PA NT COOPERATION TREAT

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF ELECTION

(PCT Rule 61.2)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 20 April 2001 (20.04.01)	
International application No. PCT/IL99/00300	**Applicant's or agent's file reference** 037/01051
International filing date (day/month/year) 06 June 1999 (06.06.99)	**Priority date** (day/month/year)
Applicant BALAN, Adi et al	

1. The designated Office is hereby notified of its election made:

[X] in the demand filed with the International Preliminary Examining Authority on:

08 January 2001 (08.01.01)

[ ] in a notice effecting later election filed with the International Bureau on:

2. The election [X] was

[ ] was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

Claudio Borton

Telephone No.: (41-22) 338.83.38

1080

PA NT COOPERATION TREAT

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION CONCERNING
AMENDMENTS OF THE CLAIMS

(PCT Rule 62 and
Administrative Instructions, Section 417)

To:

Commissioner
US Department of Commerce
United States Patent and Trademark
Office, PCT
2011 South Clark Place Room
CP2/5C24
Arlington, VA 22202
ETATS-UNIS D'AMERIQUE

in its capacity as International Preliminary Examining Authority

Date of mailing (day/month/year)	
20 April 2001 (20.04.01)	
International application No.	International filing date (day/month/year)
PCT/IL99/00300	06 June 1999 (06.06.99)
Applicant	
ELGEMS LTD. et al	

The International Bureau hereby informs the International Preliminary Examining Authority that no amendments under Article 19 have been received by the International Bureau (Administrative Instructions, Section 417).

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer

Claudio Borton

Telephone No. (41-22) 338.83.38

Copy for the International Searching Authority (ISA/US) PCT/IL99/00300

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF RECEIPT OF RECORD COPY

(PCT Rule 24.2(a))

To:

FENSTER, Paul
Fenster & Company
Patent Attorneys, Ltd.
P.O. Box 10256
49002 Petach Tikva
ISRAËL

Date of mailing (day/month/year)	IMPORTANT NOTIFICATION
15 July 1999 (15.07.99)	
Applicant's or agent's file reference	**International application No.**
037/01051	PCT/IL99/00300

The applicant is hereby notified that the International Bureau has received the record copy of the international application as detailed below.

Name(s) of the applicant(s) and State(s) for which they are applicants:

ELGEMS LTD. (for all designated States except US)
BALAN, Adi et al (for US)

International filing date	:	06 June 1999 (06.06.99)
Priority date(s) claimed	:	
Date of receipt of the record copy by the International Bureau	:	25 June 1999 (25.06.99)
List of designated Offices	:	

AP :GH,GM,KE,LS,MW,SD,SL,SZ,UG,ZW
EA :AM,AZ,BY,KG,KZ,MD,RU,TJ,TM
EP :AT,BE,CH,CY,DE,DK,ES,FI,FR,GB,GR,IE,IT,LU,MC,NL,PT,SE
OA :BF,BJ,CF,CG,CI,CM,GA,GN,GW,ML,MR,NE,SN,TD,TG
National :AE,AL,AM,AT,AU,AZ,BA,BB,BG,BR,BY,CA,CH,CN,CU,CZ,DE,DK,EE,ES,FI,GB,GD,GE,GH,GM,HR,HU,ID,IL,IN,IS,JP,KE,KG,KP,KR,KZ,LC,LK,LR,LS,LT,LU,LV,MD,MG,MK,MN,MW,MX,NO,NZ,PL,PT,RO,RU,SD,SE,SG,SI,SK,SL,TJ,TM,TR,TT,UA,UG,US,UZ,VN,YU,ZA,ZW

ATTENTION

The applicant should carefully check the data appearing in this Notification. In case of any discrepancy between these data and the indications in the international application, the applicant should immediately inform the International Bureau.

In addition, the applicant's attention is drawn to the information contained in the Annex, relating to:

- [X] time limits for entry into the national phase
- [ ] confirmation of precautionary designations
- [ ] requirements regarding priority documents

A copy of this Notification is being sent to the receiving Office and to the International Searching Authority.

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No. (41-22) 740.14.35

Authorized officer:
Dominique DELMAS

Telephone No. (41-22) 338.83.38

PATENT COOPERATION TREATY

BM

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

FENSTER, Paul
Fenster & Company
Patent Attorneys, Ltd.
P.O. Box 10256
49002 Petach Tikva
ISRAËL

Date of mailing (day/month/year) 29 July 1999 (29.07.99)	
Applicant's or agent's file reference 037/01051	**IMPORTANT NOTIFICATION**
International application No. PCT/IL99/00300	**International filing date** (day/month/year) 06 June 1999 (06.06.99)

1. The following indications appeared on record concerning:

[X] the applicant [X] the inventor [ ] the agent [ ] the common representative

Name and Address	State of Nationality	State of Residence
SHREM, Ygal 29 Keren Hayesod Street 34970 Haifa Israel	IL	IL
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [X] the name [ ] the address [ ] the nationality [ ] the residence

Name and Address	State of Nationality	State of Residence
SHREM, Yigal 29 Keren Hayesod Street 34970 Haifa Israel	IL	IL
	Telephone No.	
	Facsimile No.	
	Teleprinter No.	

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[X] the International Searching Authority
[ ] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[ ] the elected Offices concerned
[ ] other:

The International Bureau of WIPO **34, chemin des Colombettes** **1211 Geneva 20, Switzerland**	Authorized officer Dominique DELMAS
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

From the INTERNATIONAL BUREAU

PCT

NOTIFICATION OF THE RECORDING OF A CHANGE

(PCT Rule 92bis.1 and Administrative Instructions, Section 422)

To:

FENSTER, Paul
Fenster & Company
Patent Attorneys, Ltd.
P.O. Box 10256
49002 Petach Tikva
ISRAËL

Date of mailing (day/month/year)
29 July 1999 (29.07.99)

Applicant's or agent's file reference
037/01051

IMPORTANT NOTIFICATION

International application No.
PCT/IL99/00300

International filing date (day/month/year)
06 June 1999 (06.06.99)

1. The following indications appeared on record concerning:

[X] the applicant [X] the inventor [ ] the agent [ ] the common representative

Name and Address
BERLAD, Gideon
51/11 Biram Street
34986 Haifa
Israel

State of Nationality: IL
State of Residence: IL
Telephone No.:
Facsimile No.:
Teleprinter No.:

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:

[ ] the person [ ] the name [X] the address [ ] the nationality [ ] the residence

Name and Address
BERLAD, Gideon
11/52 Biram Street
34986 Haifa
Israel

State of Nationality: IL
State of Residence: IL
Telephone No.:
Facsimile No.:
Teleprinter No.:

3. Further observations, if necessary:

4. A copy of this notification has been sent to:

[X] the receiving Office
[X] the International Searching Authority
[ ] the International Preliminary Examining Authority
[ ] the designated Offices concerned
[ ] the elected Offices concerned
[ ] other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer
Dominique DELMAS

Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

3

Applicant's or agent's file reference 037/01051	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/IL99/00300	International filing date *(day/month/year)* 06 June 1999 (06.06.1999)	Priority date *(day/month/year)*
International Patent Classification (IPC) or national classification and IPC IPC(7): G01T 1/161, 1/166 and US Cl.: 250/363.04, 363.05, 363.08, 363.09		
Applicant ELGEMS LTD.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   ☑ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☒ Non-establishment of report with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☒ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand 08 January 2001 (08.01.2001)	Date of completion of this report 28 August 2001 (28.08.2001)
Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Seungsook Ham Telephone No. (703)308-0956

Form PCT/IPEA/409 (cover sheet)(July 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL99/00300

I. Basis of the report

1. With regard to the elements of the international application:*

☐ the international application as originally filed.

☒ the description:
pages 1-21 as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____.

☒ the claims:
pages NONE, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages 22-30, filed with the letter of 21 August 2001 (21.08.2001)

☒ the drawings:
pages 1-10, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____.

☐ the sequence listing part of the description:
pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____.

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

☐ the language of a translation furnished for the purposes of international search (under Rule23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination(under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in printed form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☒ The amendments have resulted in the cancellation of:

☐ the description, pages NONE

☒ the claims, Nos. 64-83

☐ the drawings, sheets/~~fig~~ NONE

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

*** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL99/00300

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The question whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been and will not be examined in respect of:

☐ the entire international application,

☒ claims Nos. 9-17, 50

because:

☐ the said international application, or the said claim Nos. ____ relate to the following subject matter which does not require international preliminary examination *(specify)*:

☐ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. ____ are so unclear that no meaningful opinion could be formed *(specify)*:

☐ the claims, or said claims Nos. ____ are so inadequately supported by the description that no meaningful opinion could be formed.

☒ no international search report has been established for said claims Nos. 9-17 and 50

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

☐ the written form has not been furnished or does not comply with the standard.

☐ the computer readable form has not been furnished or does not comply with the standard.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL99/00300

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

- ☐ restricted the claims.
- ☒ paid additional fees.
- ☐ paid additional fees under protest.
- ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention is accordance with Rules 13.1, 13.2 and 13.3 is

- ☐ complied with.
- ☒ not complied with for the following reasons:

Group I, claim(s) 1-8, 29-49, and 51-63, drawn to a method and apparatus for producing attenuation corrected nuclear medicine images;

Group II, claim(s) 18-28, drawn to a method of mounting a CT imager on a gantry;

and it considers that the International Application does not comply with the requirements of unity of invention (Rules 13.1, 13.2 and 13.3) for the reasons indicated below:

Group I is directed to a group of inventions wherein the special technical features are directed to the production of nuclear medicine images comprising acquiring nuclear image data and x-ray data. The inventions of Group I lack special technical feature directed to mounting a CT imager on a gantry;

Group II is directed to a group of inventions wherein the special technical features are directed to the mounting of a CT imager on a gantry. The inventions of Group II lack special technical feature directed to producing a nuclear medicine image.

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

- ☒ all parts.
- ☐ the parts relating to claims Nos. ____

WRITTEN OPINION

International application No.
PCT/IL99/00300

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. STATEMENT

Novelty (N)	Claims 1-8, 18-49, and 51-63	YES
	Claims NONE	NO
Inventive Step (IS)	Claims 1-8, 18-49, and 52-63	YES
	Claims 51	NO
Industrial Applicability (IA)	Claims 1-8, 18-49, and 51-63	YES
	Claims NONE	NO

2. CITATIONS AND EXPLANATIONS

Please See Continuation Sheet

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL99/00300

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No Patent No.	Publication Date *(day/month/year)*	Filing Date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
US 6,194,724 B1	27 February 2001 (27.02.2001)	05 September 1997 (05.09.1997)	05 September 1996 (05.09.1996)
US 6,171,243 B1	09 January 2001 (09.01.2001)	30 May 1997 (30.05.1997)	None

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

V. 2. Citations and Explanations:

Claim 51 lacks an inventive step under PCT Article 33(3) as being obvious over Gullberg.

Regarding claim 51, Gullberg discloses (Figs 1, 3) an apparatus for producing attenuation corrected nuclear medicine images including: a plurality of gamma cameras (22b, 22c) that acquire nuclear image data at a plurality of positions about an axis; at least one x-ray CT imager (22a) that acquires x-ray data at a plurality of positions about an axis; and an x-ray tube (col. 3, line 57).

Although Gullberg does not specifically identify the x-ray tube as a stationary anode x-ray tube, those skilled in the art appreciate that such x-ray tubes are readily available at relatively low cost.

Therefore it would not have constituted an inventive step to specify that the x-ray tube is a stationary anode x-ray tube in view of the ready availability at relatively low cost.

Claims 1-6 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest an apparatus for producing nuclear medicine images of patients including at least one gamma camera and at least one x-ray CT imager and further including a controller for providing gated NM imaging wherein the gamma camera and the x-ray imager rotate at different rotation rates.

Claims 7-8 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a nuclear medicine imaging camera having x-ray imaging capability including at least one gamma camera and an x-ray CT imager mounted on the same gantry wherein the gamma camera and the x-ray imager are capable of simultaneously rotating about a common axis at different rotation rates.

Claims 18-28 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a method of mounting a CT imager on a gantry including at least the steps of determining a center of rotation of the gantry and siting a plurality of mounting elements at predetermined positions with respect to the center of rotations; and attaching the mounting elements to the rotor while keeping the mounting elements at the predetermined positions.

Claims 29-40 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a method of nuclear imaging including at least the steps of: acquiring nuclear emission data over a first axially extending portion of the body; determining an extent of the region of interest; and acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent.

Claims 41-47 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a method of acquiring attenuation data for correcting a nuclear image comprising at least the steps of: determining an extent of the region of interest; acquiring nuclear emission data over a first axially extending portion of the body larger than the organ of interest; and acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent of the organ.

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Claims 48-49 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a method producing a nuclear medicine image comprising at least the steps of: acquiring nuclear imaging data by a gamma camera; acquiring x-ray imaging data by detectors irradiated by an x-ray source; and reducing the sensitivity of the gamma camera while the x-rays are produced.

Claims 52-60 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest an apparatus for producing a nuclear medicine image of a subject at least one gamma camera and an x-ray CT imager, and wherein the x-ray CT imager has a capability of producing a CT image having an RMS noise level of only about 10 Hounsfield numbers or more.

Claims 61-63 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest an apparatus for producing a nuclear medicine image of a subject at least one gamma camera and an x-ray CT imager, and wherein the x-ray CT imager has a capability of producing a CT image having a resolution of only about 2 lp/cm or less.

Claims 1-8, 18-49, and 51-63 have industrial applicability in the field of medical imaging.

PCT/IL 99/00300
IPEA/US 21 AUG 2001

CLAIMS

1. Apparatus for producing attenuation corrected nuclear medicine images of patients, comprising:

at least one gamma camera head that acquires nuclear image data suitable to produce a nuclear tomographic image at a first controllable rotation rate about an axis;

at least one X-ray CT imager that acquires X-ray data suitable to produce an attenuation image for correction of the nuclear tomographic image at a second controllable rotation rate about the axis; and

a controller that controls the data acquisition and first and second rotation rates to selectively provide at least one of the following modes of operation:

(i) a movement gated NM imaging mode in which the second rotation rate is substantially higher than the first rotation rate and the data from each view of the X-ray acquisition is associated with one of a plurality of respiration gated time periods;

(ii) a cardiac gated NM imaging mode in which the second rotation rate is substantially higher than the first rotation rate and the data from each view of the X-ray acquisition for different rotations is averaged, wherein the X-ray data is not correlated with the cardiac cycle; and

(iii) a cardiac gated NM imaging mode in which the second rotation rate is higher than the first rotation rate and the X-ray data is binned in accordance with a same binning as the NM data.

2. Apparatus according to claim 1 wherein the controller controls the data acquisition and first and second rotation rates to provide at least two of the modes of operation.

3. Apparatus according to claim 1 wherein the controller controls the data acquisition and first and second rotation rates to provide all three of the modes of operation.

4. Apparatus according to claim 1 or claim 2 wherein the provided modes of operation include at least mode (i).

5. Apparatus according to claim 1 or claim 2 wherein the provided modes of operation include at least mode (ii).

6. Apparatus according to claim 1 or claim 2 wherein the provided modes of operation include at least mode (iii).

7. A nuclear medicine camera having an X-ray imaging capability, comprising:

at least one gamma camera mounted on a gantry; and

an X-ray CT imager mounted on the same gantry,

wherein the at least one gamma camera and said X-ray imager are capable of simultaneously rotating about a common axis at different rotation rates.

8. A nuclear medicine camera according to claim 7 wherein the at least one gamma camera and said X-ray imager are capable of simultaneously rotating about a common axis at the same rotation rate.

9. A nuclear medicine camera having an X-ray imaging capability, comprising:

a gantry having a stationary portion and at least one rotating portion;

at least one gamma camera mounted on a said at least one rotating portion and capable of being rotated together at a common first rotation rate about an axis, said at least one gamma camera being capable of acquiring nuclear imaging data for reconstructing a tomographic nuclear image; and

an X-ray CT imager having an X-ray source mounted on said at least one rotating portion and being capable of acquiring X-ray imaging data for reconstructing an X-ray image;

said X-ray CT imager being mounted closer to said stationary portion than said at least one gamma camera.

10. A system according to claim 9 wherein the X-ray CT imager is mounted between the at least one gamma camera and stationary portion.

11. A system according to claim 9 wherein the at least one gamma camera comprises two gamma cameras.

12. A system according to claim 11 wherein the two gamma cameras have a controllable angle between them and including a controller that controls the angle between the gamma cameras.

13. A system according to claim 10 wherein the at least one gamma camera comprises two gamma cameras.

14. A system according to claim 13 wherein the two gamma cameras have a controllable angle between them and including a controller that controls the angle between the gamma cameras.

15. A system according to any of claims 9-14 wherein the X-ray imager utilizes a fixed anode X-ray to produce X-rays.

16. A system according to any of claims 9-14 wherein the X-ray source is capable of simultaneously rotating about the axis at a rotation rate different from that of the rotation rate of the gamma camera.

17. A system according to claim 15 wherein the X-ray source is capable of simultaneously rotating about the axis at a rotation rate different from that of the rotation rate of the gamma camera.

18. A method of mounting a CT imager on a gantry:

determining a center of rotation of a rotor of the gantry;

siting a plurality of mounting elements at predetermined positions with respect to the center of rotation; and

attaching the mounting elements to the rotor while keeping the mounting elements at the predetermined positions.

19. A method according to claim 18 and including:

providing a positioning jig referenced to said center of rotation; and

attaching said mounting elements on said jig.

20. A method according to claim 19 wherein said method comprises:
centering a post at the center of rotation; and
mounting said jig on said post.

21. A method according to any of claims 18-20 and including:
providing an X-ray source wherein the source is referenced to a first mounting reference thereon;
providing an X-ray detector system wherein the detector is referenced to a second mounting surface thereon; and
mounting the X-ray source and X-ray detector on said attached mounting elements.

22. A method according to claim 21 wherein the mounting elements comprise alignment elements which mate with matching elements on the first and second mounting references.

23. A method according to any of claims 18-20 wherein attaching comprises gluing.

24. A method according to any of claims 18-20 wherein attaching comprises attaching with screws.

25. A method according to claim 21 wherein attaching comprises gluing.

26. A method according to claim 21 wherein attaching comprises attaching with screws.

27. A method according to claim 22 wherein attaching comprises gluing.

28. A method according to claim 22 wherein attaching comprises attaching with screws.

29. A method of nuclear imaging, including acquiring attenuation data for correcting the nuclear image, comprising:
acquiring nuclear emission data over a first axially extending portion of the body;
determining an extent of a radioactive region of interest in the body; and
acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent.

30. A method according to claim 29 wherein the second axially extending portion is smaller than the first axially extending portion.

31. A method according to claim 29 or claim 30 wherein determining an extent comprises acquiring a planar nuclear emission image.

32. A method according to claim 29 or claim 30 wherein determining an extent comprises: determining said extent from said acquired nuclear emission data.

33. A method according to claim 29 or claim 30 wherein the transmission data is acquired using an X-ray source.

34. A method according to claim 29 or claim 30 wherein the transmission data is acquired using a gamma ray source.

35. A method according to claim 31 wherein the transmission data is acquired using an X-ray source.

36. A method according to claim 31 wherein the transmission data is acquired using a gamma ray source.

37. A method according to claim 32 wherein the transmission data is acquired using an X-ray source.

38. A method according to claim 32 wherein the transmission data is acquired using a gamma ray source.

39. A method according to claim 33 wherein the transmission data is acquired using an X-ray source.

40. A method according to claim 33 wherein the transmission data is acquired using a gamma ray source.

41. A method of acquiring attenuation data for correcting a nuclear image, comprising:

determining an extent of an organ of interest in the body;

acquiring nuclear emission data over a first axially extending portion of the body larger than the organ of interest; and

acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent of the organ, said second portion being substantially smaller than the first portion.

42. A method according to claim 41 wherein determining an extent comprises acquiring a planar X-ray image.

43. A method according to claim 41 or claim 42 wherein the transmission data is acquired using an X-ray source.

44. A method according to claim 41 wherein determining an extent comprises acquiring a planar transmission gamma ray image.

45. A method according to claim 41 or claim 44 wherein the transmission data is acquired using a gamma ray source.

46. A method according to claim 41 wherein determining an extent comprises acquiring a planar nuclear emission image.

47. A method according to claim 41 wherein determining an extent comprises:

determining said extent from said acquired nuclear emission data.

48. A method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring X-ray imaging data suitable to produce an X-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject;

reducing the sensitivity of gamma camera head while the X-rays are produced; and

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and X-ray imaging data.

49. A method according to claim 48 wherein the gamma camera head includes a plurality of photomultiplier tubes having dynodes, wherein reducing the sensitivity includes reducing voltages on said dynodes.

50. A method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring X-ray imaging data suitable to produce an X-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject for a plurality of rotations;

averaging X-ray imaging data of a same view taken at different rotations of the X-ray source to produce averaged X-ray imaging data;

reconstructing an attenuation corrected gated nuclear medicine image utilizing the nuclear imaging data and averaged ungated X-ray imaging data.

51. Apparatus for producing attenuation corrected nuclear medicine images of patients, comprising;

a plurality of gamma camera heads that acquire nuclear image data suitable to produce a nuclear tomographic image at a plurality of positions about an axis;

at least one X-ray CT imager that acquires X-ray data suitable to produce an attenuation image for correction of the nuclear tomographic image at a plurality of positions about and axis, said X-ray CT imager comprising a stationary anode X-ray tube.

52. Apparatus for producing a nuclear medicine image of a subject, comprising:

at least one gamma camera having at least one detector mounted on a gantry and capable of rotating about an axis and of acquiring nuclear imaging data suitable to produce a nuclear tomographic image;

a C-T X-ray imager including an X-ray source, mounted on said gantry and capable of rotating about the axis and X-ray detectors separate from detectors of the gamma camera,

acquiring X-ray imaging data suitable to produce an X-ray tomographic image for attenuation correction of the gamma camera image; and

circuitry capable of reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and X-ray imaging data, said C-T X-ray imager having a capability of producing a C-T image having an RMS noise level of only about 10 Hounsfield numbers or more.

53. Apparatus according to claim 52 wherein the RMS noise level is more than 15 Houndsfield numbers.

54. Apparatus according to claim 52 wherein the RMS noise level is more than 20 Houndsfield numbers.

55. Apparatus according to claim 52 wherein the RMS noise level is more than 50 Houndsfield numbers.

56. Apparatus according to claim 52 wherein the RMS noise level is more than 100 Houndsfield numbers.

57. Apparatus according to claim 52 wherein the RMS noise level is less than about 200 Houndsfield numbers.

58. Apparatus according to any of claims 52-57 the X-ray imager is only capable of producing a tomographic image having a resolution poorer than about 2 lp/cm in a transaxial direction.

59. Apparatus according to claim 58 wherein the resolution is poorer than about 3 lp/cm.

60. A apparatus according to claim 58 wherein the resolution is poorer than about 4 lp/cm.

61. Apparatus for producing a nuclear medicine image of a subject, comprising:

at least one gamma camera having at least one detector mounted on a gantry and capable of rotating about an axis and of acquiring nuclear imaging data suitable to produce a nuclear tomographic image;

a C-T X-ray imager including an X-ray source, mounted on said gantry and capable of rotating about the axis and X-ray detectors separate from detectors of the gamma camera, acquiring X-ray imaging data suitable to produce an X-ray tomographic image for attenuation correction of the gamma camera image; and

circuitry capable of reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and X-ray imaging data, said C-T X-ray imager having a capability of producing a C-T image having a resolution of only about 2 lp/cm or less.

62. Apparatus according to claim 61 wherein the resolution is poorer than about 3 lp/cm.

63. Apparatus according to claim 61 wherein the resolution is poorer than about 4 lp/cm.

PF

PATENT COOPERATION TREATY

From the
INTERNATIONAL PRELIMINARY EXAMINING AUTHORITY

To:
MAIER FENSTER
FENSTER & COMPANY PATENT ATTORNEYS, LTD.
P.O. BOX 10256
PETACH TIKVA, ISRAEL 49002

PCT

NOTIFICATION OF TRANSMITTAL OF INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Rule 71.1)

Date of Mailing *(day/month/year)*	06 SEP 2001
Applicant's or agent's file reference	**IMPORTANT NOTIFICATION**
037/01051	

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IL99/00300	06 June 1999 (06.06.1999)	

Applicant

ELGEMS LTD.

1. The applicant is hereby notified that this International Preliminary Examining Authority transmits herewith the international preliminary examination report and its annexes, if any, established on the international application.

2. A copy of the report and its annexes, if any, is being transmitted to the International Bureau for communication to all the elected Offices.

3. Where required by any of the elected Offices, the International Bureau will prepare an English translation of the report (but not of any annexes) and will transmit such translation to those Offices.

4. **REMINDER**

The applicant must enter the national phase before each elected Office by performing certain acts (filing translations and paying national fees) within 30 months from the priority date (or later in some Offices)(Article 39(1))(see also the reminder sent by the International Bureau with Form PCT/IB/301).

Where a translation of the international application must be furnished to an elected Office, that translation must contain a translation of any annexes to the international preliminary examination report. It is the applicant's responsibility to prepare and furnish such translation directly to each elected Office concerned.

For further details on the applicable time limits and requirements of the elected Offices, see Volume II of the PCT Applicant's Guide.

Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Seungsook Ham Telephone No. (703)308-0956

Form PCT/IPEA/416 (July 1992)

PATENT COOPERATION TREATY

PCT

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
037/01051		
International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/IL99/00300	06 June 1999 (06.06.1999)	
International Patent Classification (IPC) or national classification and IPC		
IPC(7): G01T 1/161, 1/166 and US Cl.: 250/363.04, 363.05, 363.08, 363.09		
Applicant		
ELGEMS LTD.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 8 sheets, including this cover sheet.

   ☑ This report is also accompanied by ANNEXES, i.e., sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 9 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the report
   - II ☐ Priority
   - III ☒ Non-establishment of report with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☒ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
08 January 2001 (08.01.2001)	28 August 2001 (28.08.2001)
Name and mailing address of the IPEA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Seungsook Ham Telephone No. (703)308-0956

Form PCT/IPEA/409 (cover sheet)(July 1998)

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL99/00300

I. Basis of the report

1. With regard to the **elements** of the international application:*

☐ the international application as originally filed.

☒ the description:
pages 1-21 as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____.

☒ the claims:
pages NONE, as originally filed
pages NONE, as amended (together with any statement) under Article 19
pages NONE, filed with the demand
pages 22-30, filed with the letter of 21 August 2001 (21.08.2001)

☒ the drawings:
pages 1-10, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____.

☐ the sequence listing part of the description:
pages NONE, as originally filed
pages NONE, filed with the demand
pages NONE, filed with the letter of _____.

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.
These elements were available or furnished to this Authority in the following language _____ which is:

☐ the language of a translation furnished for the purposes of international search (under Rule23.1(b)).

☐ the language of publication of the international application (under Rule 48.3(b)).

☐ the language of the translation furnished for the purposes of international preliminary examination(under Rules 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

☐ contained in the international application in printed form.

☐ filed together with the international application in computer readable form.

☐ furnished subsequently to this Authority in written form.

☐ furnished subsequently to this Authority in computer readable form.

☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. ☒ The amendments have resulted in the cancellation of:

☐ the description, pages NONE

☒ the claims, Nos. 64-83

☐ the drawings, sheets/~~fig~~ NONE

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed, as indicated in the Supplemental Box (Rule 70.2(c)).**

** Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17).*

*** Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.*

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL99/00300

III. Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

1. The question whether the claimed invention appears to be novel, to involve an inventive step (to be non-obvious), or to be industrially applicable have not been and will not be examined in respect of:

☐ the entire international application,

☒ claims Nos. 9-17, 50

because:

☐ the said international application, or the said claim Nos. ____ relate to the following subject matter which does not require international preliminary examination *(specify)*:

☐ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. ____ are so unclear that no meaningful opinion could be formed *(specify)*:

☐ the claims, or said claims Nos. ____ are so inadequately supported by the description that no meaningful opinion could be formed.

☒ no international search report has been established for said claims Nos. 9-17 and 50

2. A meaningful international preliminary examination cannot be carried out due to the failure of the nucleotide and/or amino acid sequence listing to comply with the standard provided for in Annex C of the Administrative Instructions:

☐ the written form has not been furnished or does not comply with the standard.

☐ the computer readable form has not been furnished or does not comply with the standard.

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL99/00300

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees the applicant has:

- ☐ restricted the claims.
- ☒ paid additional fees.
- ☐ paid additional fees under protest.
- ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention is accordance with Rules 13.1, 13.2 and 13.3 is

- ☐ complied with.
- ☒ not complied with for the following reasons:

Group I, claim(s) 1-8, 29-49, and 51-63, drawn to a method and apparatus for producing attenuation corrected nuclear medicine images;

Group II, claim(s) 18-28, drawn to a method of mounting a CT imager on a gantry;

and it considers that the International Application does not comply with the requirements of unity of invention (Rules 13.1, 13.2 and 13.3) for the reasons indicated below:

Group I is directed to a group of inventions wherein the special technical features are directed to the production of nuclear medicine images comprising acquiring nuclear image data and x-ray data. The inventions of Group I lack special technical feature directed to mounting a CT imager on a gantry;

Group II is directed to a group of inventions wherein the special technical features are directed to the mounting of a CT imager on a gantry. The inventions of Group II lack special technical feature directed to producing a nuclear medicine image.

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

- ☒ all parts.
- ☐ the parts relating to claims Nos. ____

WRITTEN OPINION

International application No.
PCT/IL99/00300

V. Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. STATEMENT

Novelty (N)	Claims 1-8, 18-49, and 51-63	YES
	Claims NONE	NO
Inventive Step (IS)	Claims 1-8, 18-49, and 52-63	YES
	Claims 51	NO
Industrial Applicability (IA)	Claims 1-8, 18-49, and 51-63	YES
	Claims NONE	NO

2. CITATIONS AND EXPLANATIONS
Please See Continuation Sheet

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No.
PCT/IL99/00300

VI. Certain documents cited

1. Certain published documents (Rule 70.10)

Application No Patent No.	Publication Date *(day/month/year)*	Filing Date *(day/month/year)*	Priority date (valid claim) *(day/month/year)*
US 6,194,724 B1	27 February 2001 (27.02.2001)	05 September 1997 (05.09.1997)	05 September 1996 (05.09.1996)
US 6,171,243 B1	09 January 2001 (09.01.2001)	30 May 1997 (30.05.1997)	None

2. Non-written disclosures (Rule 70.9)

Kind of non-written disclosure	Date of non-written disclosure *(day/month/year)*	Date of written disclosure referring to non-written disclosure *(day/month/year)*

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

V. 2. Citations and Explanations:

Claim 51 lacks an inventive step under PCT Article 33(3) as being obvious over Gullberg.

Regarding claim 51, Gullberg discloses (Figs 1, 3) an apparatus for producing attenuation corrected nuclear medicine images including: a plurality of gamma cameras (22b, 22c) that acquire nuclear image data at a plurality of positions about an axis; at least one x-ray CT imager (22a) that acquires x-ray data at a plurality of positions about an axis; and an x-ray tube (col. 3, line 57).

Although Gullberg does not specifically identify the x-ray tube as a stationary anode x-ray tube, those skilled in the art appreciate that such x-ray tubes are readily available at relatively low cost.

Therefore it would not have constituted an inventive step to specify that the x-ray tube is a stationary anode x-ray tube in view of the ready availability at relatively low cost.

Claims 1-6 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest an apparatus for producing nuclear medicine images of patients including at least one gamma camera and at least one x-ray CT imager and further including a controller for providing gated NM imaging wherein the gamma camera and the x-ray imager rotate at different rotation rates.

Claims 7-8 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a nuclear medicine imaging camera having x-ray imaging capability including at least one gamma camera and an x-ray CT imager mounted on the same gantry wherein the gamma camera and the x-ray imager are capable of simultaneously rotating about a common axis at different rotation rates.

Claims 18-28 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a method of mounting a CT imager on a gantry including at least the steps of determining a center of rotation of the gantry and siting a plurality of mounting elements at predetermined positions with respect to the center of rotations; and attaching the mounting elements to the rotor while keeping the mounting elements at the predetermined positions.

Claims 29-40 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a method of nuclear imaging including at least the steps of: acquiring nuclear emission data over a first axially extending portion of the body; determining an extent of the region of interest; and acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent.

Claims 41-47 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a method of acquiring attenuation data for correcting a nuclear image comprising at least the steps of: determining an extent of the region of interest; acquiring nuclear emission data over a first axially extending portion of the body larger than the organ of interest; and acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent of the organ.

Supplemental Box
(To be used when the space in any of the preceding boxes is not sufficient)

Claims 48-49 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest a method producing a nuclear medicine image comprising at least the steps of: acquiring nuclear imaging data by a gamma camera; acquiring x-ray imaging data by detectors irradiated by an x-ray source; and reducing the sensitivity of the gamma camera while the x-rays are produced.

Claims 52-60 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest an apparatus for producing a nuclear medicine image of a subject at least one gamma camera and an x-ray CT imager, and wherein the x-ray CT imager has a capability of producing a CT image having an RMS noise level of only about 10 Hounsfield numbers or more.

Claims 61-63 meet the criteria set out in PCT Article 33(2)-(4), because the prior art does not teach or fairly suggest an apparatus for producing a nuclear medicine image of a subject at least one gamma camera and an x-ray CT imager, and wherein the x-ray CT imager has a capability of producing a CT image having a resolution of only about 2 lp/cm or less.

Claims 1-8, 18-49, and 51-63 have industrial applicability in the field of medical imaging.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT OR THE DECLARATION

(PCT Rule 44.1)

To:
PAUL FENSTER
FENSTER & COMPANY PATENT ATTORNEYS, LTD.
P.O. BOX 10256
49002 PETACH TIKVA
ISREAL

	Date of Mailing *(day/month/year)* 26 APR 2000
Applicant's or agent's file reference 037/01051	FOR FURTHER ACTION See paragraphs 1 and 4 below
International application No. PCT/IL99/00300	International filing date *(day/month/year)* 06 June 1999 (06.06.1999)
Applicant ELGEMS LTD.	

1. ☒ The applicant is hereby notified that the international search report has been established and is transmitted herewith.

Filing of amendments and statement under Article 19:
The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally 2 months from the date of transmittal of the international search report; however, for more details, see the notes on the accompany sheet.

Where? Directly to the International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland
Facsimile No.: (41-22) 740.14.35

For more detailed instructions, see the notes on the accompanying sheet.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect is transmitted herewith.

3. ☐ **With regard to the protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with the applicant's request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Further action(s):** The applicant is reminded of the following:

Shortly after **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application , or of the priority claim, must reach the International Bureau as provided in rules 90 *bis* 1 and 90 *bis* 3, respectively, before the completion of the technical preparations for international publication.

Within **19 months** from the priority date, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase until 30 months from the priority date (in some Offices even later).

Within **20 months** from the priority date, the applicant must perform the prescribed acts for entry into the national phase before all designated Offices which have not been elected in the demand or in a later election within 19 months from the priority date or could not be elected because they are not bound by Chapter II.

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703)305-3230	Authorized officer Seungsook Robyn Ha[illegible] Telephone No. (703) 308-0956

Form PCT/ISA/220 (July 1998)

NOTES TO FORM PCT/ISA/220

These Notes are intended to give the basic instructions concerning the filing of amendments under Article 19. The Notes are based on the requirements of the Patent Cooperation Treaty and of the Regulations and the Administrative Instructions under that Treaty. In case of discrepancy between these Notes and those requirements, the latter are applicable. For more detailed information, see also the PCT Applicant's Guide, a publication of WIPO.

In these Notes, "Article", "Rule" and "Section" refer to the provisions of the PCT, the PCT Regulations and the PCT Administrative Instructions, respectively.

INSTRUCTIONS CONCERNING AMENDMENTS UNDER ARTICLE 19

The applicant has, after having received the international search report, one opportunity to amend the claims of the international application. It should however be emphasized that, since all parts of the international application (claims, description and drawings) may be amended during the international preliminary examination procedure, there is usually no need to file amendments of the claims under Article 19 except where, e.g. the applicant wants the latter to be published for the purposes of provisional protection or has another reason for amending the claims before international publication. Furthermore, it should be emphasized that provisional protection is available in some States only.

What parts of the international application may be amended ?

The claims only.

The description and the drawings may only be amended during international preliminary examination under Chapter II.

When ? Within 2 months from the date of transmittal of the international search report or 16 months from the priority date, whichever time limit expires later. It should be noted, however, that the amendments will be considered as having been received on time if they are received by the International Bureau after the expiration of the applicable time limit but before the completion of the technical preparations for international publication (Rule 46.1).

Where not to file the amendments ?

The amendments may only be filed with the International Bureau and not with the receiving Office or the International Searching Authority (Rule 46.2).

Where a demand for international preliminary examination has been/is filed, see below.

How ? Either by cancelling one or more entire claims, by adding one or more new claims or by amending the text of one or more of the claims as filed.

A replacement sheet must be submitted for each sheet of the claims which, on account of an amendment or amendments, differs from the sheet originally filed.

All the claims appearing on a replacement sheet must be numbered in Arabic numerals. Where a claim is cancelled, no renumbering of the other claims is required. In all cases where claims are renumbered, they must be renumbered consecutively (Administrative Instructions, Section 205(b)).

What documents must/may accompany the amendments ?

Letter (Section 205(b)):

The amendments must be submitted with a letter.

The letter will not be published with the international application and the amended claims. It should not be confounded with the "Statement under Article 19(1)" (see below, under "Statement under Article 19(1)").

The letter must indicate the differences between the claims as filed and the claims as amended. It must, in particular, indicate, in connection with each claim appearing in the international application (it being understood that identical indications concerning several claims may be grouped), whether

(i) the claim is unchanged;
(ii) the claim is cancelled;
(iii) the claim is new;
(iv) the claim replaces one or more claims as filed;
(v) the claim is the result of the division of a claim as filed.

The following examples illustrate the manner in which amendments must be explained in the accompanying letter:

1. [Where originally there were 48 claims and after amendment of some claims there are 51]:
"Claims 1 to 29, 31, 32, 34, 35, 37 to 48 replaced by amended claims bearing the same numbers; claims 30, 33 and 36 unchanged; new claims 49 to 51 added."
2. [Where originally there were 15 claims and after amendment of all claims there are 11]:
"Claims 1 to 15 replaced by amended claims 1 to 11."
3. [Where originally there were 14 claims and the amendments consist in cancelling some claims and in adding new claims]:
"Claims 1 to 6 and 14 unchanged; claims 7 to 13 cancelled; new claims 15, 16 and 17 added." or
"Claims 7 to 13 cancelled; new claims 15, 16 and 17 added; all other claims unchanged."
4. [Where various kinds of amendments are made]:
"Claims 1-10 unchanged; claims 11 to 13, 18 and 19 cancelled; claims 14, 15 and 16 replaced by amended claim 14; claim 17 subdivided into amended claims 15, 16 and 17; new claims 20 and 21 added."

"Statement under Article 19(1)" (Rule 46.4)

The amendments may be accompanied by a statement explaining the amendments and indicating any impact that such amendments might have on the description and the drawings (which cannot be amended under Article 19(1)).

The statement will be published with the international application and the amended claims.

The statement should be brief, it should not exceed 500 words if in English or if translated into English.

It should not be confounded with and does not replace the letter indicating the differences between the claims as filed and as amended. It must be filed on a separate sheet and must be identified as such by a heading, preferably by using the words "Statement under Article 19(1)."

It should not contain any disparaging comments on the international search report or the relevance of citations contained in that report. Reference to citations, relevant to a given claim, contained in the international search report may be made only in connection with an amendment of that claim.

In what language ?

The amendments must be made in the language in which the international application is published. The letter and any statement accompanying the amendments must be in the same language as the international application if that language is English or French; otherwise, it must be in English or French, at the choice of the applicant.

Consequence if a demand for international preliminary examination has already been filed ?

If, at the time of filing any amendments under Article 19, a demand for international preliminary examination has already been submitted, the applicant must preferably, at the same time of filing the amendments with the International Bureau, also file a copy of such amendments with the International Preliminary Examining Authority (see Rule 62.2(a), first sentence).

Consequence with regard to translation of the international application for entry into the national phase ?

The applicant's attention is drawn to the fact that, where upon entry into the national phase, a translation of the claims as amended under Article 19 may have to be furnished to the designated/elected Offices, instead of, or in addition to, the translation of the claims as filed.

For further details on the requirements of each designated/elected Office, see Volume II of the PCT Applicant's Guide.

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 037/01051	**FOR FURTHER ACTION**	see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.
International application No. PCT/IL99/00300	International filing date (*day/month/year*) 06 June 1999 (06.06.1999)	(Earliest) Priority Date (*day/month/year*) NONE
Applicant ELGEMS LTD.		

This international search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 6 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the Report**
   a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.
   ☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).
   b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing:
   ☐ contained in the international application in written form.
   ☐ filed together with the international application in computer readable form.
   ☐ furnished subsequently to this Authority in written form.
   ☐ furnished subsequently to this Authority in computer readable form.
   ☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
   ☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.
2. ☐ **Certain claims were found unsearchable** (See Box I).
3. ☒ **Unity of invention is lacking** (See Box II).
4. With regard to the **title**,
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,
   ☐ the text is approved as submitted by the applicant.
   ☒ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No. 1A
   ☐ as suggested by the applicant.
   ☐ because the applicant failed to suggest a figure.
   ☒ because this figure better characterizes the invention.
   ☐ None of the figures

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL99/00300

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Please See Continuation Sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.
☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Inter[redacted]nal application No.

PCT/IL99/00300

Box III TEXT OF THE ABSTRACT (Continuation of Item 5 of the first sheet)

NEW ABSTRACT

A method of producing a nuclear medicine image of a subject comprising the steps of acquiring nuclear image data suitable to produce a nuclear tomographic image, the data being acquired by at least one gamma camera head (12, 14) rotating about the subject at an average first rate, acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, the data being acquired by an array of detectors (20) irradiated by an x-ray source (18) rotating around the subject at an average second rate which is within a factor of 10 of the first rate, and reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL99/00300

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G01T 1/00, 1/20
US CL : 250/363.04, 363.05, 363.08, 363.09

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 250/363.04, 363.05, 363.08, 363.09, 363.02, 378/4, 11, 15, 18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,565,684 A (GULLBERG et al.) 15 October 1996 (15.10.1996), abstract; col. 3, lines 55-58; col. 4, lines 30-39, 56-60; col. 6, lines 9-13; Figs 1-3.	1-3, 78
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Y		4-28, 31-41, 53-72, 75-77
Y	US 5,289,008 A (JASZCZAK et al.) 22 February 1994, (22.02.1994), abstract; col. 4, lines 38-50; Fig.	4-12
Y	US 5,598,003 A (JONES et al.) 28 January 1997 (28.01.1997) abstract; col. 2, line 67-col. 3, line 5; col. 6, lines 16-18, 62-65; Figs. 1-2.	10-15, 31
Y	US 4,585,008 A (JARKEWICZ) 29 April 1986 (29.04.1986), abstract, col. 7, lines 34-	16-28, 76-77
Y	US 5,391,877 A (MARKS) 21 February 1995 (21.02.1995), abstract; col. 2, lines 32-38, 62-69; Fig. 1.	16-28
Y	US 5,554,848 A (HERMONY et al.) 10 September 1996 (10.09.1996), abstract; col. 2, lines 36-47; col. 4, lines 55-67, Figs. 1-2.	16-28, 32-41, 75-77
Y	US 5,900,636 A (NELLEMANN et al.) 04.May 1999 (04.05.1999), abstract; Fig. 1.	53-72
X	US 4,014,109 A (SCHRAMM) 29 March 1977 (29.03.1977), abstract; Fig. 1.	79
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Y		80-97
Y	US 4,499,375 A (JASZCZAK) 12 February 1985 (12.02.1985), abstract; Fig. 1, 3.	80-97

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
11 April 2000 (11.04.2000)

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Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL99/00300

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,803,914 A (RYALS et al.) 08 September 1998 (08.09.1998), see entire document.	1-41, 53-78
A	US 5,717,212 A (FULTON et al.) 10 February 1998 (10.02.1998), see entire document.	42-52
A	US 4,578,585 A (GOSIS et al.) 25 March 1986 (25.03.1986) see entire document.	42-52

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL99/00300

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claim(s) 1-41 and 53-78, drawn to a method and apparatus for producing attenuation corrected nuclear medicine images.

Group II, claim(s) 42-52, drawn to a method of mounting a CT imager on a gantry.

Group III, claim(s) 79-97, drawn to a registration phantom for registering transmission and emission images.

The inventions listed as Groups I, II, and III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:
Group I is directed to a group of inventions wherein the special technical features are directed to the production of nuclear medicine images comprising acquiring nuclear image data and x-ray data. The inventions of Group I lack special technical features directed to either mounting a CT imager on a gantry or a registration phantom for registering transmission and emission images.
Group II is directed to a group of inventions wherein the special technical features are directed to the mounting of a CT imager on a gantry. The inventions of Group II lack special technical features directed to either producing a nuclear medicine image or a registration phantom for registering transmission and emission images.
Group III is directed to a group of inventions wherein the special technical features are directed to a registration phantom for registering transmission and emission images. The inventions of Group III lack special technical features directed to either producing a nuclear medicine image or mounting a CT imager on a gantry.

Continuation of B. FIELDS SEARCHED Item 3: USPTO APS EAST search terms: emission, transmission, gamma, x-ray, attenuation correction, imaging, noise, resolution, hounsfield, phantom, registration, calibration, attach, mount, jig.

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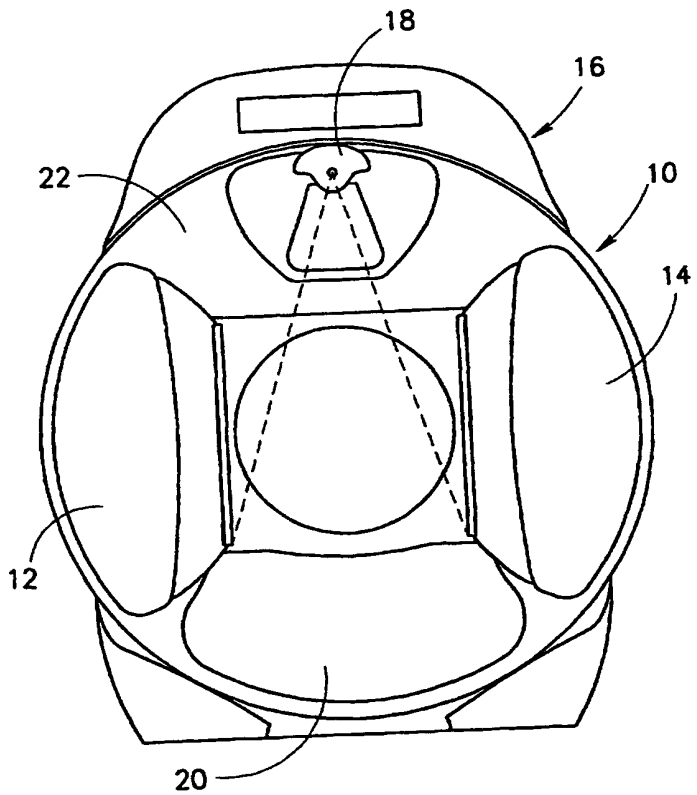
(54) Title: GAMMA CAMERA AND CT SYSTEM



(57) Abstract: A method of producing a nuclear medicine image of a subject comprising the steps of acquiring nuclear image data suitable to produce a nuclear tomographic image, the data being acquired by at least one gamma camera head (12, 14) rotating about the subject at an average first rate, acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, the data being acquired by an array of detectors (20) irradiated by an x-ray source (18) rotating around the subject at an average second rate which is within a factor of 10 of the first rate, and reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data.

WO 00/75691 A1

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

GAMMA CAMERA AND CT SYSTEM

FIELD OF THE INVENTION

The present invention is related to the field of nuclear medicine and in particular to gamma cameras with x-ray transmission imaging for localization and attenuation correction of nuclear images.

BACKGROUND OF THE INVENTION

Attenuation correction in nuclear medicine imaging is well known in the art. In particular, it is well known when producing SPECT or PET images to correct the images for the effect of attenuation of the gamma rays used for producing the image by intervening tissue and bone. In particular, it is known to generate an attenuation map (three dimensional image or a series of two dimensional slices) of the region being imaged by the gamma camera and correcting the counts of gamma events based on the attenuation of the tissue and bone between the source of the gamma ray and the detector.

The attenuation image is produced in some prior art devices using a source of gamma rays to produce a nuclear CT (attenuation) image. X-ray based CT attenuation images are used in other prior art devices. Devices which utilize the same detector for acquiring both emission and transmission images have been reported as well as devices which utilize different detectors for acquiring the images. Devices utilizing both single and multiple detectors for acquisition of one or both of the images are also known.

In general, prior art devices which utilize X-rays for producing the attenuation map use separate gantries for the X-ray and gamma ray imaging sub-systems. Systems of this type are described, for example, in US Patent 5,391,877, the disclosure of which is incorporated herein by reference. However, this requires matching between the attenuation maps and the nuclear medicine images. Other systems utilize the same gantry for both the X-ray and gamma ray imaging systems. Such systems are described for example in US Patent 5,376,795, the disclosure of which is incorporated herein by reference.

SUMMARY OF THE INVENTION

An aspect of some preferred embodiments of the invention is concerned with a system which has PET, SPECT and X-ray CT capabilities. In preferred embodiments according to this aspect, the system can perform either x-ray, SPECT or PET three dimensional imaging (or multiple slices of two dimensions).

An aspect of some preferred embodiments of the invention is concerned with the relative speeds of detector rotation of gamma camera heads for the acquisition of data for SPECT imaging and of X-ray detectors for acquisition of data for CT reconstruction for the

attenuation correction map. In particular, in accordance with some preferred embodiments of the invention, the CT image is acquired at a low rotation rate, comparable to the rate of rotation of the gamma camera heads. Alternatively, but less preferably, the X-ray data is acquired at a high rotation rate, and preferably over several rotations. The data from the same angle for the various rotations is then averaged. Additionally or alternatively, lower quality CT data is acquired to match the Gamma camera resolution and noise level.

This allows for three important advantages. Firstly, this allows for matching between the conditions under which the data is acquired, i.e., the same averaging of body motion is intrinsic for both acquisitions. Second, a slow rotation rate gantry may be used. Third, lower X-ray power may be used. This allows for a smaller power supply and for a smaller gantry, of the size and type normally suitable for gamma cameras alone.

In some preferred embodiments of the invention, the power of the X-ray energy is adjusted to provide an optimum energy per view by operating in a pulsed mode, in which the pulse duty cycle is designed to give a desired signal to noise in X-ray data. The data may also be adjusted by providing quasi DC to the X-ray tube. That is to say, the duration of the X-ray is controlled to be sufficient to provide the desired total X-ray energy.

An aspect of some preferred embodiments of the invention is concerned with a gamma camera which can create transmission and attenuation maps utilizing two detectors oriented 90^{o} degrees apart, 180^{o} apart or at any selectable angle between 90^{o} and 180^{o}.

An aspect of some preferred embodiments of the invention is concerned with the reduction of the amount of radiation utilized for the acquisition of the attenuation image. In accordance with a preferred embodiment of the invention, the NM image is acquired first. Then data for the attenuation image is acquired only over a range of the patient's body for which the NM image is of interest. In particular, the attenuation image is acquired only for a region containing organs of interest (as identified from the NM image) or, over regions of the body for which activity is identified in the NM image.

An aspect of some preferred embodiments of the invention is concerned with the electrification of the X-ray system and the Gamma camera heads. In accordance with a preferred embodiment of the invention, a common set of conduits supplies power to the X-ray system and the Gamma camera heads. In some preferred embodiments of the invention, the X-ray generator used for attenuation data acquisition, including its power supply, are mounted on the gantry, such that only low voltage need be transferred to the rotating gantry. This transfer may be achieved by using slip rings or long coiled cables.

An aspect of some preferred embodiments of the invention is concerned with the transfer of data from X-ray detectors and Gamma ray detectors to an image reconstruction system. In a preferred embodiment of the invention the outputs of the X-ray detectors and the gamma camera head or heads is digitized. The digitized signals are sent, via a common data transmission line or lines to a common computer system. In a preferred embodiment of the invention, the data is transmitted by a common conductor or optical cable system. In another preferred embodiment, the data is transmitted by a wireless link, for example an optical link or a radio link.

In a related aspect of some preferred embodiments of the invention, the same computer infrastructure, such as reconstruction algorithms and/or a common CPU is used to reconstruct both NM and X-ray images.

An aspect of some preferred embodiments of the invention is concerned with a combined NM and X-ray CT system which operates in one or more of a plurality of modes. For example, some possible modes are:

1) An ungated NM imaging mode, in which the X-ray detectors rotate together with the NM detectors or in which the X-ray detectors make a number of rotations and the data from the same view for different rotations is averaged.

2) A respiration gated NM imaging mode in which the CT data is acquired in a high rotation rate mode, and the data from each view is associated with one of the respiration gated time periods. In this mode, unaveraged CT data may be used to generate a higher resolution, if noisier image.

3) A respiration gated NM imaging mode in which CT data is acquired over one or a very few rotations while the patient holds his breath. The CT image is then used to correct an NM image that corresponds to this condition.

4) A cardiac gated NM imaging mode in which the CT data is acquired either in a slow rotation rate mode or in a fast rotation rate mode, with averaging of the data. In this mode, the attenuation data is not correlated with the cardiac cycle. However, the CT image is based on averaged data over the cardiac cycle.

5) A cardiac gated NM imaging mode in which the CT data is acquired in a fast rotation rate mode with gating of the CT data in accordance with the same binning as the NM data.

An aspect of some preferred embodiments of the invention is concerned with the construction of a combined NM/X-ray CT system. In some preferred embodiments of the invention, the relationship between the X-ray and NM systems are fixed with respect to rotational position. This system, while structurally simple, must take data for the X-ray and NM

images separately, unless the rotation rate for the two is the same as in some of the above modes of operation. In some preferred embodiments of the invention, a single main gantry is provided. One of the two sets of data acquisition systems rotates with the main gantry. The second acquisition system is mounted on and rotates with respect to the main gantry.

An aspect of some preferred embodiments of the invention involves the alignment and calibration of a combined CT/NM imaging system. In preferred embodiments of the invention, the structure of the CT portion of the system is very simple as compared with dedicated CT systems, since the alignment and power requirements and the weight of the system are all greatly reduced. In order to simplify the adjustment of the X-ray system and especially the field replacement of the X-ray system, a method of alignment based on a standard alignment surface and position and a method of providing these surfaces without accurate machining of these surfaces. In a preferred embodiment of the invention, the alignment surfaces are mounted onto the gantry by screws, based on a position determined by an alignment jig centered at the center of rotation of the gantry. More preferably, the alignment surfaces are attached to the gantry by glue. Due to the relatively light weight of the X-ray system, these mounting methods are both efficient and secure.

In a preferred embodiment of the invention, the X-ray system and the NM system are axially displaced (along the axis of rotation). Preferably, the X-ray system is mounted closer to gantry support that is the NM system.

There is thus provided in accordance with a preferred embodiment of the invention, a method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject at an average first rate;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject at an average second rate, said second rate being within a factor of 10 of the first rate; and

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data. Preferably, the second rate and the first rate are substantially the same. Preferably, the first and second rates are the same.

There is also provided in accordance with a preferred embodiment of the invention, a method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject; and

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data, said x-ray tomographic image having an RMS noise level of more than about 10 Hounsfield numbers. Preferably, the RMS noise level is more than 15 Hounsfield numbers. Preferably, the RMS noise level is more than 20 Hounsfield numbers. Preferably, the RMS noise level is more than 50 Hounsfield numbers. Preferably, the RMS noise level is more than 100 Hounsfield numbers. In a preferred embodiment of the invention, the RMS noise level is less than about 200 Hounsfield numbers.

In a preferred embodiment of the invention, the x-ray tomographic image has a resolution poorer than about 2 lp/cm in a transaxial direction. Preferably, the resolution is poorer than about 3 lp/cm. Preferably, the resolution is poorer than about 4 lp/cm.

There is also provided in accordance with a preferred embodiment of the invention, a method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject; and

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data, said x-ray tomographic image having a resolution poorer than about 2 lp/cm. Preferably, the resolution is poorer than about 3 lp/cm. Preferably, the resolution is poorer than about 4 lp/cm.

There is also provided in accordance with a preferred embodiment of the invention, apparatus for producing attenuation corrected nuclear medicine images of patients, comprising:

at least one gamma camera head that acquires nuclear image data suitable to produce a nuclear tomographic image at a first controllable rotation rate about an axis;

at least one X-ray CT imager that acquires X-ray data suitable to produce an attenuation image for correction of the nuclear tomographic image at a second controllable rotation rate about the axis; and

a controller that controls the data acquisition and first and second rotation rates to selectively provide at least two of the following seven modes of operation:

(i) an ungated NM imaging mode, in which the first and second rotation rates are the same;

(ii) an ungated NM imaging mode in which the X-ray detectors make a number of rotations and the data from each view of the X-ray acquisition for different rotations is averaged;

(iii) a movement gated NM imaging mode in which the second rotation rate is substantially higher than the first rotation rate and the data from each view of the x-ray acquisition is associated with one of a plurality of respiration gated time periods;

(iv) a respiration gated NM imaging mode in which CT data is acquired over one or a very few rotations while the patient holds his breath, the CT image being used to correct an NM image that corresponds to this condition;

(v) a cardiac gated NM imaging mode in which the second rotation rate is substantially the same as the first rotation rate or in which the second rotation rate is substantially higher than the first rotation rate and the data from each view of the X-ray acquisition for different rotations is averaged, wherein the X-ray data is not correlated with the cardiac cycle;

(vi) a cardiac gated NM imaging mode in which the second rotation rate is higher than the first rotation rate and the X-ray data is binned in accordance with a same binning as the NM data; and

(vii) a cardiac gated NM imaging mode in which the X-ray data is which the second rotation rate is substantially the same as the first rotation rate and the X-ray data is binned in accordance with a same binning as the NM data. Preferably, the controller controls the data acquisition and first and second rotation rates to provide at least three of the modes of operation. Preferably, the controller controls the data acquisition and first and second rotation rates to provide at least four of the modes of operation. Preferably, the controller controls the data acquisition and first and second rotation rates to provide at least five of the modes of operation. Preferably, the controller controls the data acquisition and first and second rotation rates to provide at least six of the modes of operation. Preferably, the controller controls the data acquisition and first and second rotation rates to provide all of the modes of operation.

In a preferred embodiment of the invention, the provided modes of operation include at least mode (i). Alternatively or additionally, the provided modes of operation include at least mode (ii). Alternatively or additionally, the provided modes of operation include at least mode (iii). Alternatively or additionally, the provided modes of operation include at least mode (iv).

Alternatively or additionally, the provided modes of operation include at least mode (v). Alternatively or additionally, the provided modes of operation include at least mode (vi). Alternatively or additionally, the provided modes of operation include at least mode (vii).

There is also provided in accordance with a preferred embodiment of the invention, a nuclear medicine camera having an X-ray imaging capability, comprising:

at least one gamma camera mounted on a gantry; and

an X-ray CT imager mounted on the same gantry,

wherein the at least one gamma camera and said X-ray imager are capable of simultaneously rotating about a common axis at different rotation rates. Preferably, the at least one gamma camera and said X-ray imager are capable of simultaneously rotating about a common axis at the same rotation rate.

There is also provided in accordance with a preferred embodiment of the invention, a nuclear medicine camera having an X-ray imaging capability, comprising:

a pair of gamma cameras mounted on a gantry and capable of being rotated together at a common first rotation rate about an axis, said pair of gamma cameras having a controllable angle therebetween and being capable of acquiring nuclear imaging data for reconstructing a tomographic nuclear image; and

an X-ray CT imager mounted on the same gantry and being capable of acquiring x-ray imaging data for reconstructing a x-ray image; and

a controller that controls the angle between the gamma cameras.

There is also provided in accordance with a preferred embodiment of the invention, a nuclear medicine camera having an X-ray imaging capability, comprising:

at least one gamma camera mounted on a rotor of a gantry and being capable of acquiring nuclear imaging data for reconstructing a nuclear image; and

an X-ray CT imager mounted on a rotating portion of the same gantry and being capable of acquiring x-ray imaging data for reconstructing a x-ray image;

image processing circuitry not situated on a rotating portion of the gantry; and

a common conduit for transferring said nuclear and X-ray imaging data to said circuitry. Preferably, the camera includes additional image processing circuitry mounted on the rotating portion of the gantry, said additional circuitry providing preliminary processing to at least one of the x-ray and nuclear imaging data prior to said transferring. Alternatively or additionally, the image processing circuitry is used to reconstruct the CT and NM images. Preferably, common circuitry is used to reconstruct the CT and NM images. Preferably, the common circuitry comprises a same CPU.

In a preferred embodiment of the invention, the camera comprises common software used to reconstruct the CT and NM images. Alternatively or additionally, the camera comprises a multiplexer which multiplexes the nuclear and x-ray data prior to said transmission. Preferably, the camera comprises a demultiplexer that demultiplexes the nuclear and x-ray data after said transmission.

In a preferred embodiment of the invention, the common conduit includes slip rings. Alternatively or additionally, the common conduit includes a wireless link.

There is also provided in accordance with a preferred embodiment of the invention, a method of mounting a CT imager on a gantry:

determining a center of rotation of a rotor of the gantry;

siting a plurality of mounting elements at predetermined positions with respect to the center of rotation; and

attaching the mounting elements to the rotor while keeping the mounting elements at the predetermined positions. Preferably, the method comprises:

providing a positioning jig referenced to said center of rotation; and

attaching said mounting elements on said jig. Preferably, the method comprises:

centering a post at the center of rotation; and

mounting said jig on said post.

In a preferred embodiment of the invention, the method comprises:

providing an x-ray source wherein the source is referenced to a first mounting reference thereon;

providing an x-ray detector system wherein the detector is referenced to a second mounting surface thereon; and

mounting the x-ray source and x-ray detector on said attached mounting elements. Preferably, the mounting elements comprise alignment elements which mate with matching elements on the first and second mounting references.

In a preferred embodiment of the invention, attaching comprises gluing. Alternatively or additionally, attaching comprises attaching with screws.

There is also provided in accordance with a preferred embodiment of the invention, apparatus for producing attenuation corrected nuclear medicine images of patients, comprising;

a plurality of gamma camera heads that acquire nuclear image data at a plurality of positions about an axis, suitable to produce a nuclear tomographic image ;

at least one X-ray CT imager that acquires X-ray data suitable to produce an attenuation image for correction of the nuclear tomographic image at a plurality of positions about and axis;

image processing circuitry that produces attenuation corrected nuclear images utilizing said nuclear and x-ray data; and

a controller that controls the data acquisition and image processing circuitry to selectively operate in SPECT mode in which a SPECT image is produced and a PET mode in which a PET image is produced.

There is also provided in accordance with a preferred embodiment of the invention, a method of nuclear imaging, including acquiring attenuation data for correcting the nuclear image, comprising:

acquiring nuclear emission data over a first axially extending portion of the body;

determining an extent of a radioactive region of interest in the body; and

acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent. Preferably, the second axially extending portion is smaller than the first axially extending portion. Alternatively or additionally, determining an extent comprises acquiring a planar nuclear emission image. Alternatively or additionally, determining an extent comprises determining said extent from said acquired nuclear emission data.

In a preferred embodiment of the invention, the transmission data is acquired using an x-ray source. Alternatively or additionally, the transmission data is acquired using a gamma ray source.

There is also provided in accordance with a preferred embodiment of the invention, a method of acquiring attenuation data for correcting a nuclear image, comprising:

determining an extent of an organ of interest in the body;

acquiring nuclear emission data over a first axially extending portion of the body larger than the organ of interest; and

acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent of the organ, said second portion being substantially smaller than the first portion. Preferably, determining an extent comprises acquiring a planar x-ray image. Alternatively or additionally, the transmission data is acquired using an x-ray source. Alternatively or additionally, determining an extent comprises acquiring a planar transmission gamma ray image. Alternatively or additionally, the transmission data is acquired using a gamma ray source. Alternatively or additionally, determining an extent comprises acquiring a planar nuclear emission image.

In a preferred embodiment of the invention, determining an extent comprises determining said extent from said acquired nuclear emission data.

There is also provided in accordance with a preferred embodiment of the invention, a method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject;

reducing the sensitivity of gamma camera head while the X-rays are produced; and

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data. Preferably, the gamma camera head includes a plurality of photomultiplier tubes having dynodes, wherein reducing the sensitivity includes reducing voltages on said dynodes.

There is also provided in accordance with a preferred embodiment of the invention, a method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject for a plurality of rotations;

averaging x-ray imaging data of a same view taken at different rotations of the X-ray source to produce averaged X-ray imaging data;

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and the averaged x-ray imaging data. Preferably, the method includes binning the x-ray data with respect to a physical variable, and wherein said averaging is performed on data in the same bin and having the same view. Alternatively or additionally, the method includes gating the x-ray responsive to a physical variable.

There is also provided in accordance with a preferred embodiment of the invention, apparatus for producing attenuation corrected nuclear medicine images of patients, comprising;

a plurality of gamma camera heads that acquire nuclear image data suitable to produce a nuclear tomographic image at a plurality of positions about an axis;

at least one X-ray CT imager that acquires X-ray data suitable to produce an attenuation image for correction of the nuclear tomographic image at a plurality of positions about and axis, said X-ray CT imager comprising a stationary anode X-ray tube.

There is also provided in accordance with a preferred embodiment of the invention, a registration phantom for registering transmission and emission imaging systems, comprising:

a substantially attenuating phantom body formed with a plurality of cavities; and

radio-emissive material filling the cavities. Preferably, at least one of the cavities is a long thin cavity. Alternatively or additionally, at least one of the cavities is a spherical cavity. Alternatively or additionally, the phantom includes a plurality of radio-opaque marking elements axially offset from said cavities.

In a preferred embodiment of the invention, the phantom includes at least three such cavities. Preferably, the phantom includes at least four such cavities. Preferably, the phantom includes at least six said cavities.

There is also provided in accordance with a preferred embodiment of the invention, a method of determining a coordinate transformation between a nuclear emission imaging system and a transmission imaging system comprising:

providing a phantom having elements that are imageable by said nuclear emission imaging system and elements imageable by said transmission imaging system;

imaging said phantom by both said systems to provide emission and transmission images of the phantom; and

determining the transformation from a comparison of said emission and transmission images. Preferably, the transmission images are X-ray images. Alternatively or additionally, the transmission images are gamma ray images.

In a preferred embodiment of the invention, the phantom comprises:

a phantom body formed with a plurality of cavities; and

radio-emissive material filling the cavities. Preferably, the phantom comprises a plurality of radio-opaque marking elements axially offset from said cavities. Alternatively or additionally, at least one of the cavities is a long thin cavity. Alternatively or additionally, at least one of the cavities is a spherical cavity.

In a preferred embodiment of the invention, the radio-emissive material is radio-opaque.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will be more clearly understood from the following description of the preferred embodiments thereof, taken together with the following drawings, in which:

Figs. 1A and 1B are end views of a gamma camera system with attenuation correction, in accordance with a preferred embodiment of the invention;

Fig. 1C is a side view of the gamma camera system of Figs. 1A and 1B;

Fig. 1D schematically shows circuitry for information transfer, control and image reconstruction, for the system of Figs. 1A-1C; and

Fig. 2-8 illustrate the alignment of an X-ray CT imaging system in accordance with a preferred embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Fig. 1A and 1B illustrate end views and Fig. 1C illustrates a lateral view of a gamma camera system 10, with attenuation correction, in accordance with a preferred embodiment of the invention. Camera system 10 preferably comprises a pair of gamma camera heads 12 and 14 and an X-ray imaging system 16. System 16 preferably comprises an X-ray source 18 and a plurality of X-ray detectors arranged in an array 20. Camera heads 12 and 14 and system 16 are preferably mounted on a same gantry 22, as shown in Figs. 1A-1C. However, for some preferred embodiments of the invention (which may not embody all the above mentioned aspects of the invention) the camera heads and the X-ray system are mounted on different gantries. For some preferred embodiments of the invention, only a single gamma camera head is required. In others three or four heads, equally spaced circumferentially about the axis of rotation are used.

A patient (not shown in Figs. 1A-1C) is preferably placed on a table 102 which is advanced along an axis of rotation of camera heads 12 and 14 and system 16. A radio-isotope is selectively situated inside the patient, by conventional means such as via the blood stream (intravenous injection) or the lungs (inhalation) or by other means known in the art. Preferably, heads 12 and 14 generate nuclear imaging data signals in response to gamma rays generated by the radioisotopes.

Similarly, X-ray source 18 irradiates the patient, and array 20 generates X-ray data signals, in response to X-rays from source 18 which impinge on the X-ray detectors, after passing through the patient.

As shown in Figs. 1A and 1B, the angle between heads 12 and 14 is preferably adjustable between 90 degrees and 180 degrees, using conventional means. Furthermore, the distance between the heads may be adjusted and the transverse positions of each of the heads (or of both together) may be adjusted, using conventional mechanical structures. Alternatively, the heads are fixed at one of the positions of Figs. 1A and 1B. Further alternatively, three

gamma cameras may be provided, namely the two shown in Fig. 1B plus a third camera, below and between the two cameras shown.

Referring additionally to Fig. 1D, in a preferred embodiment of the invention, the nuclear energy signals and the X-ray signals are digitized in digitizers 24 (and 24') and 26, respectively to produce digital signals on lines 28 and 30 respectively. Digitizing by digitizers 24 and 26 may be preceded by some signal processing and/or image pre-processing, as known in the art. In a preferred embodiment of the invention, the signals on lines 26 and 28 are multiplexed (and optionally compressed) by a multiplexer 32 and fed to a computer 34 via a transmission system 36. Alternatively, one or both of the x-ray and emission data (SPECT/PET) are preprocessed in corresponding hardware/software and then fed into multiplexer 32. It should be understood that in most of the embodiments shown herein PET or SPECT imaging may be performed. In preferred embodiments of the invention, the NM imaging mode may be switched between PET and SPECT.

In computer 34, the signals are de-multiplexed (and if necessary, decompressed) for processing (utilizing algorithms known in the art) to produce three dimensional (or two dimensional slice) images. These images which may be displayed on a display 38, stored in a memory in the computer, or both. Preferably, the nuclear images are corrected for attenuation of intervening tissue and bones, three-dimensional attenuation images produced from data generated from the transmission (X-ray) signals. Such correction may use any of the algorithms known in the art.

In general, the nuclear medicine data may include raw data (the outputs of photomultiplier tubes or pixelized detectors of the camera heads) or calculated positions of detected nuclear events on the heads (either uncorrected positions or positions corrected for camera head distortions). In producing the nuclear image and the transmission (attenuation) image, the (angular) position of the camera heads and the x-ray system and the lineal position of the table with respect to the heads and x-ray system are taken into account by computer 34. These positions are preferably measured by transducers or encoders or by other means, as known in the art.

In a preferred embodiment of the invention, the same CPU and/or other hardware infrastructure is used in generating both the nuclear medicine image and the attenuation image used to correct it. Alternatively or additionally, the same software is used to generate the three dimensional nuclear medicine and attenuation images. In general, the reconstruction algorithms used for X-ray CT reconstruction and SPECT reconstruction are the same or very similar. Some types of PET reconstruction also use some of the same algorithms used for CT reconstruction.

In general, use of the same hardware, and to some extent, of the same software, allows for a less expensive overall system cost. Of course, achieving these advantages does not necessarily require that the data be multiplexed and transmitted over the same line or transmission channel, as described above.

However, in a preferred embodiment of the invention, digitizers 24 and 26, lines 28 and 30 and multiplexer 32 are mounted on the moving portion of gantry 30. Thus, if only a single transmission system 36 is required, there is a considerable saving in system complexity and cost. In a preferred embodiment of the invention, transmission system 36 comprises a slip ring system. In an alternate preferred embodiment of the invention, the transmission system comprises a radio or optical link. Alternatively, the transmission system comprises a coiled transmission line which unwinds as the camera heads rotate. In any event, the use of a single link greatly simplifies the transmission of data to the computer and reduces the complexity of the transmission system.

In a preferred embodiment of the invention, the nuclear imaging signals and the x-ray signals are preferably acquired over different extents of the patient. In a preferred embodiment of the invention, transmission data is acquired only for axial slices for which significant nuclear activity is indicated or may be expected. For other slices, no attenuation correction data is acquired and the nuclear image is not corrected for attenuation. This more limited acquisition of transmission data means that the patient is irradiated by the X-rays for a shorter time and over a smaller portion of his body.

The portion of the patient's body over which transmission data should be acquired may be determined in a number of ways. For example, a low energy, one dimensional transmission X-ray "scout" image may be acquired to locate the position of an organ of interest. The scout image is preferably "assembled" by computer 34 and displayed on display 38. In a preferred embodiment of the invention, an operator indicates the extent of the organ, on the image, to computer 34. A controller 40, receives commands from computer 34 and activates X-ray source 14, responsive to the commands, only for those axial positions for which radiation is necessary to correct for attenuation. The patient is irradiated with X-rays only over the axial extent of the organ or other region of interest.

Alternatively or additionally, the uncorrected nuclear image or a planar nuclear image is acquired first and displayed. The extent of region of nuclear activity is determined, either by the operator, or automatically by the computer. A transmission image is then acquired as indicated above, only for this axial region.

Alternatively, the nuclear data is analyzed for nuclear activity, on a slice by slice basis, to determine if transmission data is to be acquired.

It should be noted that while in a preferred embodiment of the invention, an X-ray transmission system is utilized, the advantages of reduced transmission radiation exposure can also be achieved when a radio-nuclide source is used for transmission imaging. Preferably, a shutter is used to cover the radio nuclide source when transmission imaging data is not required.

Alternatively or additionally, in a preferred embodiment of the invention, the X-ray energy used to irradiate the patient is further reduced by reducing the quality requirements for the X-ray CT transmission image below that normally required for such images. In general, CT images are acquired at a relatively high X-ray energy in order to allow for the reconstruction of high quality attenuation images. However, attenuation images utilized for correction of nuclear medicine images may be degraded to match the image quality levels (spatial resolution, signal to noise and other such factors) of the nuclear image. Thus, while normal CT imaging utilizes X-ray levels suitable for 10-20 lp/cm resolutions, for attenuation corrections, a spatial resolution of 1-3 or even 4 lp/cm is sufficient. Additionally, while an RMS noise level of 1-5 Hounsfield numbers is generally considered to be required for CT imaging, CT imaging for attenuation correction requires only a noise level of about 10, 20, 50, 100 or even 200 Hounsfield numbers. This results in an X-ray system having much lower energy and power requirements than those of "standard" CT systems and a much lower weight. Importantly, the amount of radiation to which the patient is exposed from the transmission source is greatly reduced. Furthermore, the alignment accuracy required for the CT system is also reduced, since the accuracy of alignment required is reduced in proportion to the reduced resolution. These reduced requirements allow for the mounting of an appropriate CT system on a nuclear medicine gantry, without the normal strict mechanical requirements for a CT system.

It should be noted that as used herein the term "energy" means "power times time" and not photon energy.

A further reduction of weight can be achieved by reducing the power required in addition to the total energy required. In particular, while CT imaging is generally performed at a rotation rate of up to 2 Hz, CT imaging for attenuation correction can be performed (in some circumstances, as described below) at rotation rates compatible with those utilized for the acquisition of nuclear imaging data. These rotation rates may be as fast as 3 cycles per minute, but are generally slower that that. Thus, normal X-ray CT rotation rates are more than an order

of magnitude faster than normal NM rotation rates and those used in preferred embodiments of the present invention.

The reduction in energy can be achieved in one of a number of ways. One way is to reduce the power of the CT. This may be advantageous even if the total energy is not reduced, since it can result in a lower cost and weight X-ray system (for example, using a fixed anode tube and/or using a smaller power supply, preferably mounted on the rotor of the gantry (to avoid transfer of high voltages to a moving rotor).

One way of reducing the power is to use a less powerful X-ray source. This can reduce the weight and cost of the system substantially. A lower cost stationary anode X-ray tube can be used. Alternatively or additionally, the power supply for the tube mounted on and preferably integrated with the tube on the rotor. This allows for transfer of line voltage, rather than high voltage, to the rotor for the X-ray supply. Alternatively, a higher power tube may be used and the tube pulsed for only a short time (low duty cycle). This pulsing can take place for example when the X-ray system is in a position in which data should be acquired. This can also allow for a system with the same or similar benefits.

In a preferred embodiment of the invention, the relative speeds of rotation of the nuclear and X-ray imaging systems are controlled and optimized to provide improved images, depending on the type of image being acquired. In particular, a system in accordance with this embodiment is capable of operating in one or more of the following modes:

1) An ungated NM imaging mode, in which the X-ray detectors rotate together with the NM detectors or in which the X-ray detectors make a number of rotations and the data from the same view for different rotations is averaged.

2) A respiration gated NM imaging mode in which the CT data is acquired in a high rotation rate mode, and the data from each view is associated with one of the respiration gated time periods. In this mode, unaveraged CT data may be used to generate a higher resolution, if noisier image.

3) A respiration gated NM imaging mode in which CT data is acquired over one or a very few rotations while the patient holds his breath. The CT image is then used to correct an NM image that corresponds to this (breath holding) condition.

4) A cardiac gated NM imaging mode in which the CT data is acquired either in a slow rotation rate mode or in a fast rotation rate mode with averaging of the data to simulate slow rotation. In this mode, the attenuation data is not correlated with the cardiac cycle. However, the CT image is based on averaged data over the cardiac cycle.

5) A cardiac gated NM imaging mode in which the CT data is acquired in a fast rotation rate mode with gating of the CT data in accordance with the same or similar binning as the NM data.

In a preferred embodiment of the invention, computer 34 is supplied with a user input 42. A user may choose from one of a series of protocols, which may have one or more of the above rotation rate relationships.

In one preferred embodiment of the invention, the nuclear medicine and x-ray systems are mounted on a single rotating element and thus, rotate together. For such systems, acquisition of X-ray and Nuclear Medicine image data at different rotation rates (as is common in the art) requires that the nuclear medicine system be rotated at a much higher rate than is usual for such systems. In addition to subjecting the gamma camera heads to undue stress, this requires a much heavier and more expensive gantry.

Therefore, in a preferred embodiment of the invention, means are provided for rotating the two imaging systems independently. In one preferred embodiment of the invention, the two imaging systems are mounted on separate gantries, as in the above referenced US Patent 5,391,877. In others, a single gantry is provided. However, a plurality of different concentric bearings are provided. One of these allows for the rotation of one of the imaging systems with respect to the fixed reference while the other allows for the rotation of the second imaging system with respect to the first imaging system. This may be achieved, for example, by mounting the gamma cameras on an outer ring which rotates, on bearings, mounted in a fixed portion of the gantry. The X-ray system is mounted on a second ring which rotates on bearings mounted on the outer ring. The rings are driven by separate motors. This construction assures that the two systems rotate about a common axis, which aids in alignment and correlating of the imaging systems.

In a preferred embodiment of the invention, a single power line is used to supply all of the equipment which rotates. As shown in Fig. 1D, controller 40 activates the X-ray system when transmission data is required. In addition, controller 40 may be used to distribute power to the X-ray detector electronics, and the gamma camera heads. This use of a single power line for the moving portions of the gantry results in reduced system complexity and costs. The line power may be transferred utilizing, for example, slip rings. Alternatively, it may be transferred utilizing a rolled up cable, which unwinds as the heads and X-ray system rotates. Controller 40, whose function may be distributed over a number of controllers, is preferably situated on the moving portion and preferably receives its commands via the same multiplexed transmission link, described above, used for data transfer.

In a preferred embodiment of the invention, the Nuclear medicine system can be operated in one of several modes:

1) PET- The nuclear detectors are preferably fitted with one or two dimensional widely spaced septa to block large angle coincidence events. Alternatively no septa are used. Coincidence events are acquired over one or more rotations of detectors 12 and 14.

2) SPECT-The nuclear detectors are fitted with Multi-channel collimators to detect gamma radiation. The detectors may be used singly, or together at 90 or 180 degree apart configurations. A series of views are taken about at least 180 degrees of the patient. (Only 90 degrees of rotation of the gantry is required for the 90 degree detector configuration.) In each view detectors 12 and 14 can be moved close to the patient to improve resolution of the images.

3) Whole Body - In each of PET and SPECT as described above, the detectors image a large axial distance of 400-500 mm. Larger areas can be covered by translating the patient axially. This axial translation may be performed in steps, between rotations of detectors 12 and 14, or continuously while rotating the detectors, in a spiral mode.

In each of the above modes, the NM data can be complemented with X-ray attenuation data derived from X-ray transmission imaging. The X-ray images may be acquired before, during or after the SPECT or PET images. As indicated above, the X-ray images may be acquired over only a part of the axial length of the scan and may be acquired in a step and shoot or helix mode.

Emission and transmission scans may be interlaced with each other or the emission sequences may all be taken together. For longer scans, simultaneous transmission and emission imaging may take place over different portions of the body.

In a preferred embodiment of the invention the photomultiplier tubes (PMTs) are turned off or their sensitivity is reduced while the X-ray is on. This is desirable, since the x-ray flux is very high and can saturate and blind the PMTs. One possible methodology is to turn off the PMTs completely. However, if the PMTs are turned off, the cameras take a substantial time to stabilize after they are turned on again. In a preferred embodiment of the invention, the PMT dynode voltages are reduced, thus substantially reducing the gain of the PMTs and avoiding blinding and damage to the PMTs. Additionally or alternatively, an x-ray filter may be placed over the detector. However, due to the high flux of x-rays, this is often not sufficient by itself.

The alignment and mounting of an X-ray CT imaging system in accordance with a preferred embodiment of the invention, is illustrated with reference to Figs. 2-8.

Fig. 2 shows a system 10 prior to the mounting of the X-ray system. As illustrated, the gamma camera heads are already mounted; however, the gamma camera heads, whose

alignment is not critical, may be mounted after the mounting of the X-ray system. On Fig. 2, the rotating portion (rotor) of the gantry (on which the X-ray system is to be mounted) is indicated by reference 50 and the stationary portion (stator) of the system is indicated by reference 52.

The first stage of the alignment process, illustrated in Fig. 3, is the establishment of a reference to the center of rotation of the gantry. As is well known, accuracy of a CT imaging system depends on an accurate placement of the X-ray source and detectors with respect to the axis of rotation.

A rod 54 is mounted on a rod adjustment device 56, firmly attached to a fixed reference. For example, rod adjustment device 56 may be attached via a bracket 58 to stator 52. Rod adjustment device comprises two spaced apart independent x-y transverse translation mechanisms 60 and 62, to which rod 54 is attached. Two indicators 64 and 66 are mounted on and rotated rotor 50. Translation mechanisms 60 and 62 are adjusted as the rotor is rotated, until rod 54 is centered. Separate adjustment of x and y centering may be necessary. After the rod is centered, the indicators and the bracket on which they are mounted are removed.

Fig. 4 shows an end view of system 10, after the adjustment of the centering of rod 54. Rod adjustment device 56 continues to hold rod 54 although it is not shown in Fig. 4. An X-ray detector support 68 and an X-ray source support 70 are mounted on rotor 50. The positioning of supports 68 and 70 are each formed with a plurality of glue pockets 72.

These pockets are filled with glue (for example a high strength epoxy) indicated by reference 74 on Fig. 5.

Fig. 6 shows the mounting of a plurality of mounting inserts 76 on supports 68 and 70. In accordance with a preferred embodiment of the invention, as described below, X-ray source 18 and array 20 are mounted on the mounting inserts 76. The step illustrated in Fig. 6 assures that inserts 76 are aligned with the center of rotation of the system, by reference to rod 54.

A bridge 78, is mounted on rod 54. Bridge 78 has a center hole whose size closely matches the diameter of rod 54. Insert holders 80 are mounted on bridge 78 and support inserts 76 in an accurate position vis-à-vis rod 54. While the means for mounting inserts 76 on holders 80 are not shown, they typically include screws for mounting and pins for alignment of the inserts on the insert holders. The bridge is rotated until it is substantially perpendicular to a line connecting the centers of detectors 12 and 14. This adjustment is not critical and may be performed by eye. in addition, the bridge is moved axially along rod 54 until the inserts are approximately centered in pockets 72. This adjustment is not critical either.

The glue is allowed to set and harden. When the glue has hardened sufficiently, bridge 78 and holder are dismantled from rod 54 and inserts 76 leaving the inserts attached to rotor 50 by glue 74. However, due to the method of attachment, the inserts are aligned with rod 54 and hence the center of rotation of rotor 50.

Fig. 7 shows inserts 76 mounted on supports 68 and 70. Inserts 76 comprise a plurality of pins 82 and threads 84 for mounting detector array 20 and X-ray source 18. While a particular arrangement of pins and threads is shown in Fig. 7, any arrangement of pins and threads which provides positive positioning and firm mounting may be used.

Fig. 8 shows X-ray source 18 and detector array 20 after mounting. X-ray source 18 and detector array 20 are and mounted to inserts 76 by holding screws 86 and holding nuts 88. Pins 82 fit into matching holes in the housings of source 18 and detector array 20. The position and orientation of the X-ray tube and the detectors are closely aligned, in the factory with these holes, such that no additional alignment of the x-ray source and detector array is necessary.

The resulting standardization of positions and alignments allows for the simple field replacement of X-ray source and/or detectors when such replacement is necessary.

In a preferred embodiment of the invention, the relative positions of the coordinate systems of the nuclear medicine imaging system and the X-ray imaging system is determined by imaging a combined X-ray/NM phantom with both systems. A transformation is determined between the coordinate systems, based on a known relationship between NM and X-ray features in the phantom. A suitable phantom is formed with a plurality of cavities or other elements containing radioactive material. Such elements are imaged by both the CT and NM systems. Preferably, the radioactive material is opaque to x-rays. At least three such elements, preferably situated in an axial plane, are usually sufficient to align the system. Preferably 4-6 elements are provided to allow for averaging and for correction of axial skew. In a preferred embodiment of the invention, the cavities are spherical. Alternatively or additionally , at least some of the cavities are thin long cavities. Alternatively or additionally, separate elements, having known positional relationship are used for determining the transformation. Alternatively or additionally, the phantom includes a plurality of radio-opaque marking elements axially offset from said cavities.

In practice, the registration information is used to control combined CT/NM protocols in which the positions of the patient (bed) are automatically controlled for the two acquisitions.

While the gluing system described above is preferred for attaching inserts 76, more conventional positioning with shims or the like may be used, for some preferred embodiments of the invention.

In some preferred embodiments of the invention, the opening for the patient is smaller than in normal X-ray CT devices. Preferably, an arm support device (a frame that limits the radial extent of the patient by folding his arms within the frame) is provided.

The CT system as disclosed may be a single slice CT or a multi-slice CT, in which a plurality of rows of detectors allow for the acquisition of multiple slices of CT data at one time. Alternatively, a large array of detectors may be provided, and a cone beam of X-ray may by used to image a field of view that is similar to or the same as that of the NM detectors.

The present invention has been described using non-limiting detailed descriptions of preferred embodiments thereof that are provided by way of example and are not intended to limit the scope of the invention. Variations of embodiments described will occur to persons of the art. In addition, while preferred embodiments of the invention have been described as having certain groups of features, some preferred embodiments of the invention may include fewer of more of the features or other combinations of features. Furthermore, the terms "comprise," include," and "have" or their conjugates shall mean: "including but not necessarily limited to." The scope of the invention is limited only by the following claims:

CLAIMS

1. A method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject at an average first rate;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject at an average second rate, said second rate being within a factor of 10 of the first rate; and

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data.

2. A method according to claim 1 wherein the second rate and the first rate are substantially the same.

3. A method according to claim 2 wherein the first and second rates are the same.

4. A method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject; and

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data, said x-ray tomographic image having an RMS noise level of more than about 10 Hounsfield numbers.

5. A method according to claim 4 wherein the RMS noise level is more than 15 Houndsfield numbers.

6. A method according to claim 4 wherein the RMS noise level is more than 20 Houndsfield numbers.

7. A method according to claim 4 wherein the RMS noise level is more than 50 Houndsfield numbers.

8. A method according to claim 4 wherein the RMS noise level is more than 100 Houndsfield numbers.

9. A method according to claim 4 wherein the RMS noise level is less than about 200 Houndsfield numbers.

10. A method according to any of claims 4-9 wherein the x-ray tomographic image has a resolution poorer than about 2 lp/cm in a transaxial direction.

11. A method according to claim 10 wherein the resolution is poorer than about 3 lp/cm.

12. A method according to claim 10 wherein the resolution is poorer than about 4 lp/cm.

13. A method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject; and

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data, said x-ray tomographic image having a resolution poorer than about 2 lp/cm.

14. A method according to claim 13 wherein the resolution is poorer than about 3 lp/cm.

15. A method according to claim 13 wherein the resolution is poorer than about 4 lp/cm.

16. Apparatus for producing attenuation corrected nuclear medicine images of patients, comprising:

at least one gamma camera head that acquires nuclear image data suitable to produce a nuclear tomographic image at a first controllable rotation rate about an axis;

at least one X-ray CT imager that acquires X-ray data suitable to produce an attenuation image for correction of the nuclear tomographic image at a second controllable rotation rate about the axis; and

a controller that controls the data acquisition and first and second rotation rates to selectively provide at least two of the following seven modes of operation:

(i) an ungated NM imaging mode, in which the first and second rotation rates are the same;

(ii) an ungated NM imaging mode in which the X-ray detectors make a number of rotations and the data from each view of the X-ray acquisition for different rotations is averaged;

(iii) a movement gated NM imaging mode in which the second rotation rate is substantially higher than the first rotation rate and the data from each view of the x-ray acquisition is associated with one of a plurality of respiration gated time periods;

(iv) a respiration gated NM imaging mode in which CT data is acquired over one or a very few rotations while the patient holds his breath, the CT image being used to correct an NM image that corresponds to this condition;

(v) a cardiac gated NM imaging mode in which the second rotation rate is substantially the same as the first rotation rate or in which the second rotation rate is substantially higher than the first rotation rate and the data from each view of the X-ray acquisition for different rotations is averaged, wherein the X-ray data is not correlated with the cardiac cycle;

(vi) a cardiac gated NM imaging mode in which the second rotation rate is higher than the first rotation rate and the X-ray data is binned in accordance with a same binning as the NM data; and

(vii) a cardiac gated NM imaging mode in which the X-ray data is which the second rotation rate is substantially the same as the first rotation rate and the X-ray data is binned in accordance with a same binning as the NM data.

17. Apparatus according to claim 16 wherein the controller controls the data acquisition and first and second rotation rates to provide at least three of the modes of operation.

18. Apparatus according to claim 16 wherein the controller controls the data acquisition and first and second rotation rates to provide at least four of the modes of operation.

19. Apparatus according to claim 16 wherein the controller controls the data acquisition and first and second rotation rates to provide at least five of the modes of operation.

20. Apparatus according to claim 16 wherein the controller controls the data acquisition and first and second rotation rates to provide at least six of the modes of operation.

21. Apparatus according to claim 16 wherein the controller controls the data acquisition and first and second rotation rates to provide all of the modes of operation.

22. Apparatus according to any of claims 16-20 wherein the provided modes of operation include at least mode (i).

23. Apparatus according to any of claims 16-20 wherein the provided modes of operation include at least mode (ii).

24. Apparatus according to any of claims 16-20 wherein the provided modes of operation include at least mode (iii).

25. Apparatus according to any of claims 16-20 wherein the provided modes of operation include at least mode (iv).

26. Apparatus according to any of claims 16-20 wherein the provided modes of operation include at least mode (v).

27. Apparatus according to any of claims 16-20 wherein the provided modes of operation include at least mode (vi).

28. Apparatus according to any of claims 16-20 wherein the provided modes of operation include at least mode (vii).

29. A nuclear medicine camera having an X-ray imaging capability, comprising:

at least one gamma camera mounted on a gantry; and

an X-ray CT imager mounted on the same gantry,

wherein the at least one gamma camera and said X-ray imager are capable of simultaneously rotating about a common axis at different rotation rates.

30. A nuclear medicine camera according to claim 29 wherein the at least one gamma camera and said X-ray imager are capable of simultaneously rotating about a common axis at the same rotation rate.

31. A nuclear medicine camera having an X-ray imaging capability, comprising:

a pair of gamma cameras mounted on a gantry and capable of being rotated together at a common first rotation rate about an axis, said pair of gamma cameras having a controllable angle therebetween and being capable of acquiring nuclear imaging data for reconstructing a tomographic nuclear image; and

an X-ray CT imager mounted on the same gantry and being capable of acquiring x-ray imaging data for reconstructing a x-ray image; and

a controller that controls the angle between the gamma cameras.

32. A nuclear medicine camera having an X-ray imaging capability, comprising:

at least one gamma camera mounted on a rotor of a gantry and being capable of acquiring nuclear imaging data for reconstructing a nuclear image; and

an X-ray CT imager mounted on a rotating portion of the same gantry and being capable of acquiring x-ray imaging data for reconstructing a x-ray image;

image processing circuitry not situated on a rotating portion of the gantry; and

a common conduit for transferring said nuclear and X-ray imaging data to said circuitry.

33. A camera according to claim 32 and also including additional image processing circuitry mounted on the rotating portion of the gantry, said additional circuitry providing preliminary processing to at least one of the x-ray and nuclear imaging data prior to said transferring.

34. A camera according to claim 32 wherein the image processing circuitry is used to reconstruct the CT and NM images.

35. A camera according to claim 34 wherein common circuitry is used to reconstruct the CT and NM images.

36. A camera according to claim 35 wherein the common circuitry comprises a same CPU.

37. A camera according to claim 36 and including common software used to reconstruct the CT and NM images.

38. A camera according to claim 32 and including a multiplexer which multiplexes the nuclear and x-ray data prior to said transmission.

39. A camera according to claim 38 and including a demultiplexer that demultiplexes the nuclear and x-ray data after said transmission.

40. A camera according to any of claims 32-39 wherein the common conduit includes slip rings.

41. A camera according to any of claims 32-39 wherein the common conduit includes a wireless link.

42. A method of mounting a CT imager on a gantry:

determining a center of rotation of a rotor of the gantry;

siting a plurality of mounting elements at predetermined positions with respect to the center of rotation; and

attaching the mounting elements to the rotor while keeping the mounting elements at the predetermined positions.

43. A method according to claim 42 and including:

providing a positioning jig referenced to said center of rotation; and

attaching said mounting elements on said jig.

44. A method according to claim 43 wherein said method comprises:

centering a post at the center of rotation; and

mounting said jig on said post.

45. A method according to any of claims 42-44 and including:

providing an x-ray source wherein the source is referenced to a first mounting reference thereon;

providing an x-ray detector system wherein the detector is referenced to a second mounting surface thereon; and

mounting the x-ray source and x-ray detector on said attached mounting elements.

46. A method according to claim 45 wherein the mounting elements comprise alignment elements which mate with matching elements on the first and second mounting references.

47. A method according to any of claims 42-44 wherein attaching comprises gluing.

48. A method according to any of claims 42-44 wherein attaching comprises attaching with screws.

49. A method according to claim 45 wherein attaching comprises gluing.

50. A method according to claim 45 wherein attaching comprises attaching with screws.

51. A method according to claim 46 wherein attaching comprises gluing.

52. A method according to claim 46 wherein attaching comprises attaching with screws.

53. Apparatus for producing attenuation corrected nuclear medicine images of patients, comprising;

a plurality of gamma camera heads that acquire nuclear image data at a plurality of positions about an axis, suitable to produce a nuclear tomographic image ;

at least one X-ray CT imager that acquires X-ray data suitable to produce an attenuation image for correction of the nuclear tomographic image at a plurality of positions about and axis;

image processing circuitry that produces attenuation corrected nuclear images utilizing said nuclear and x-ray data; and

a controller that controls the data acquisition and image processing circuitry to selectively operate in SPECT mode in which a SPECT image is produced and a PET mode in which a PET image is produced.

54. A method of nuclear imaging, including acquiring attenuation data for correcting the nuclear image, comprising:

acquiring nuclear emission data over a first axially extending portion of the body;

determining an extent of a radioactive region of interest in the body; and

acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent.

55. A method according to claim 54 wherein the second axially extending portion is smaller than the first axially extending portion.

56. A method according to claim 54 or claim 55 wherein determining an extent comprises acquiring a planar nuclear emission image.

57. A method according to claim 54 or claim 55 wherein determining an extent comprises:

determining said extent from said acquired nuclear emission data.

58. A method according to claim 54 or claim 55 wherein the transmission data is acquired using an x-ray source.

59. A method according to claim 54 or claim 55 wherein the transmission data is acquired using a gamma ray source.

60. A method according to claim 56 wherein the transmission data is acquired using an x-ray source.

61. A method according to claim 56 wherein the transmission data is acquired using a gamma ray source.

62. A method according to claim 57 wherein the transmission data is acquired using an x-ray source.

63. A method according to claim 57 wherein the transmission data is acquired using a gamma ray source.

64. A method according to claim 58 wherein the transmission data is acquired using an x-ray source.

65. A method according to claim 58 wherein the transmission data is acquired using a gamma ray source.

66. A method of acquiring attenuation data for correcting a nuclear image, comprising:

determining an extent of an organ of interest in the body;

acquiring nuclear emission data over a first axially extending portion of the body larger than the organ of interest; and

acquiring transmission data over a second axially extending portion of the body, responsive to the determined extent of the organ, said second portion being substantially smaller than the first portion.

67. A method according to claim 66 wherein determining an extent comprises acquiring a planar x-ray image.

68. A method according to claim 66 or claim 67 wherein the transmission data is acquired using an x-ray source.

69. A method according to claim 66 wherein determining an extent comprises acquiring a planar transmission gamma ray image.

70. A method according to claim 66 or claim 69 wherein the transmission data is acquired using a gamma ray source.

71. A method according to claim 66 wherein determining an extent comprises acquiring a planar nuclear emission image.

72. A method according to claim 66 wherein determining an extent comprises:

determining said extent from said acquired nuclear emission data.

73. A method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject;

reducing the sensitivity of gamma camera head while the X-rays are produced; and

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and x-ray imaging data.

74. A method according to claim 73 wherein the gamma camera head includes a plurality of photomultiplier tubes having dynodes, wherein reducing the sensitivity includes reducing voltages on said dynodes.

75. A method of producing a nuclear medicine image of a subject, comprising:

acquiring nuclear imaging data suitable to produce a nuclear tomographic image, said nuclear image data being acquired by a gamma camera head rotating about the subject;

acquiring x-ray imaging data suitable to produce an x-ray tomographic image for attenuation correction of the gamma camera image, said X-ray imaging data being acquired by detectors irradiated by an X-ray source rotating around the subject for a plurality of rotations;

averaging x-ray imaging data of a same view taken at different rotations of the X-ray source to produce averaged X-ray imaging data;

reconstructing an attenuation corrected nuclear medicine image utilizing the nuclear imaging data and the averaged x-ray imaging data.

76. A method according to claim 75 and including:

binning the x-ray data with respect to a physical variable, and wherein said averaging is performed on data in the same bin and having the same view.

77. A method according to claim 75 and including gating the x-ray responsive to a physical variable.

78. Apparatus for producing attenuation corrected nuclear medicine images of patients, comprising;

a plurality of gamma camera heads that acquire nuclear image data suitable to produce a nuclear tomographic image at a plurality of positions about an axis;

at least one X-ray CT imager that acquires X-ray data suitable to produce an attenuation image for correction of the nuclear tomographic image at a plurality of positions about and axis, said X-ray CT imager comprising a stationary anode X-ray tube.

79. A registration phantom for registering transmission and emission imaging systems, comprising:

a substantially attenuating phantom body formed with a plurality of cavities; and

radio-emissive material filling the cavities.

80. A phantom according to claim 79 wherein at least one of the cavities is a long thin cavity.

81. A phantom according to claim 79 wherein at least one of the cavities is a spherical cavity.

82. A phantom according to any of claims 79-81 and including a plurality of radio-opaque marking elements axially offset from said cavities.

83. A phantom according to any of claims 79-81 wherein the radio-emissive material is radio-opaque to x-rays.

84. A phantom according to any of claims 79-81 and including at least three such cavities.

85. A phantom according to any of claims 79-81 and including at least four such cavities.

86. A phantom according to any of claims 79-81 and including at least six said cavities.

87. A phantom according to claim 82 and including at least three such cavities.

88. A phantom according to claim 82 and including at least four such cavities.

89. A phantom according to claim 82 and including at least six said cavities.

90. A method of determining a coordinate transformation between a nuclear emission imaging system and a transmission imaging system comprising:

providing a phantom having elements that are imageable by said nuclear emission imaging system and elements imageable by said transmission imaging system;

imaging said phantom by both said systems to provide emission and transmission images of the phantom; and

determining the transformation from a comparison of said emission and transmission images.

91. A method according to claim 90 wherein the transmission images are X-ray images.

92. A method according to claim 90 wherein the transmission images are gamma ray images.

93. A method according to any of claims 90-93 wherein the phantom comprises:

a phantom body formed with a plurality of cavities; and

radio-emissive material filling the cavities.

94. A method according to claim 93 wherein the radio-emissive material is radio-opaque to x-rays.

95. A method according to claim 93 wherein the phantom comprises a plurality of radio-opaque marking elements axially offset from said cavities.

96. A phantom according to claim 93 wherein at least one of the cavities is a long thin cavity.

97. A phantom according to claim 93 wherein at least one of the cavities is a spherical cavity.

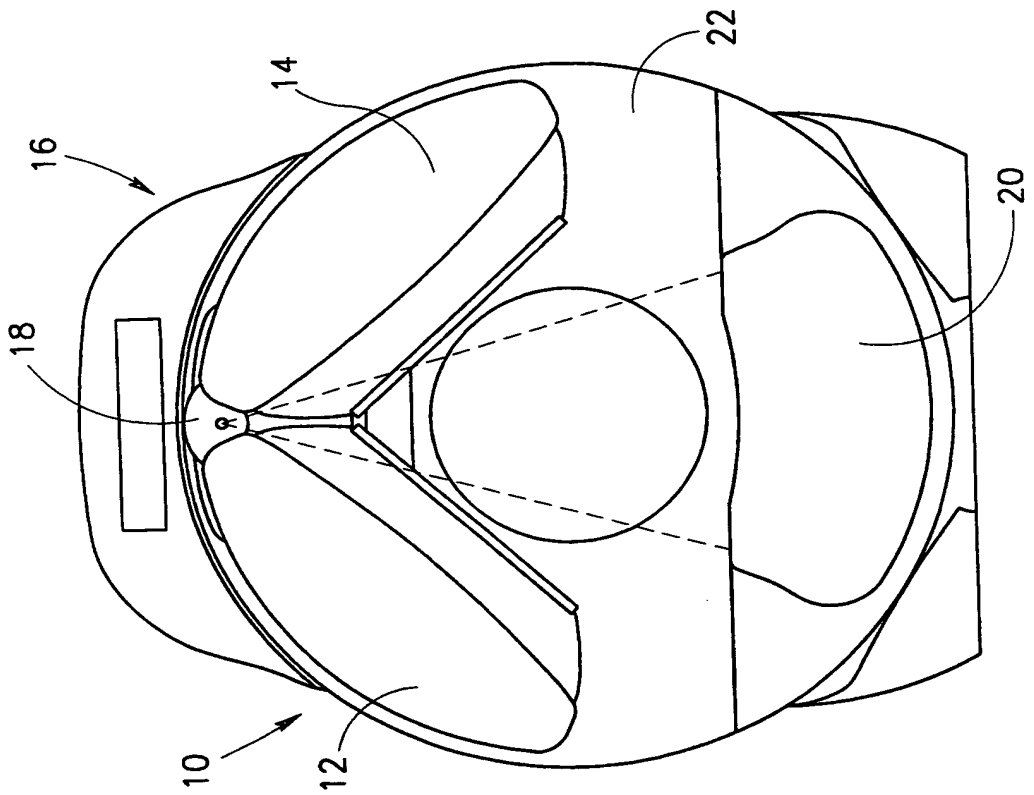


FIG.1B

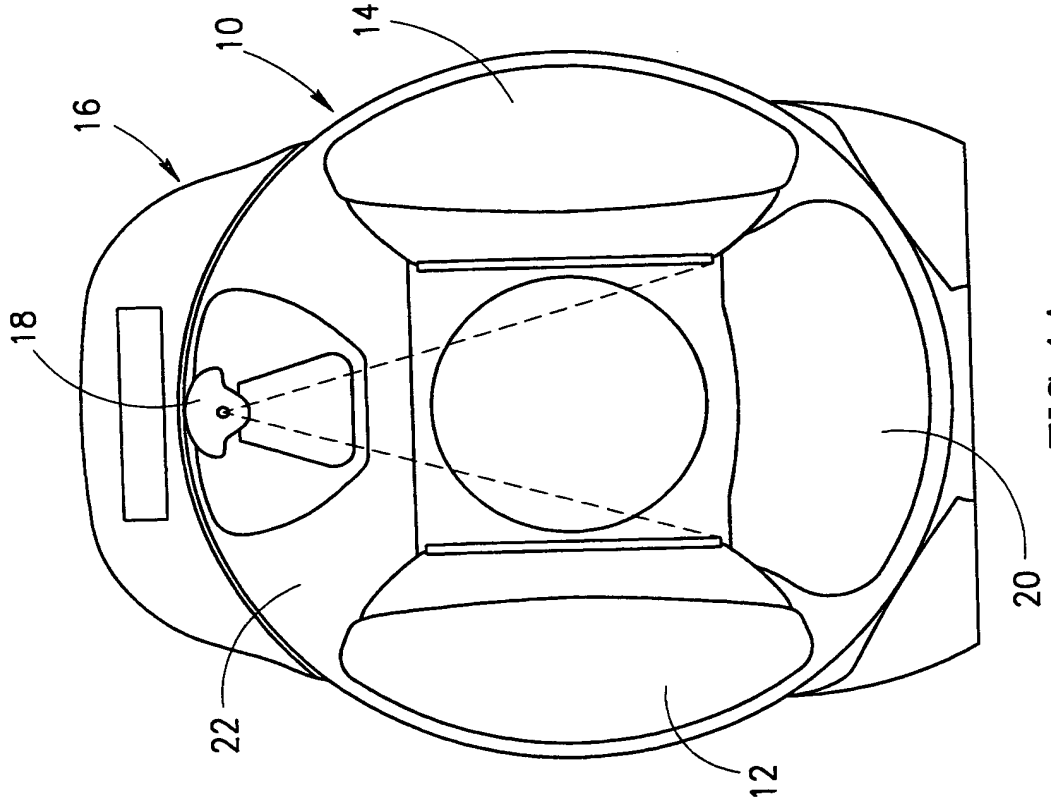


FIG.1A

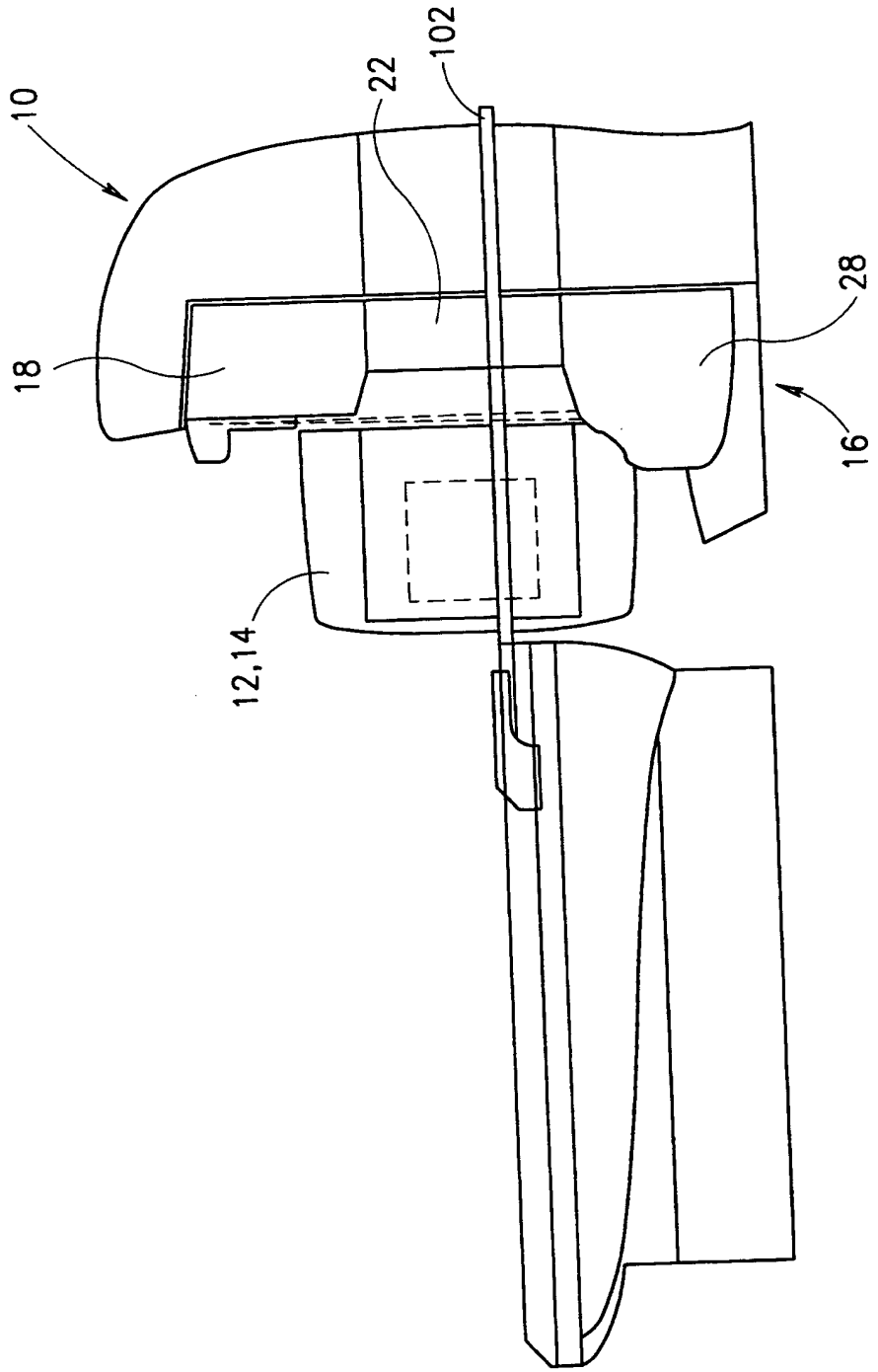


FIG.1C

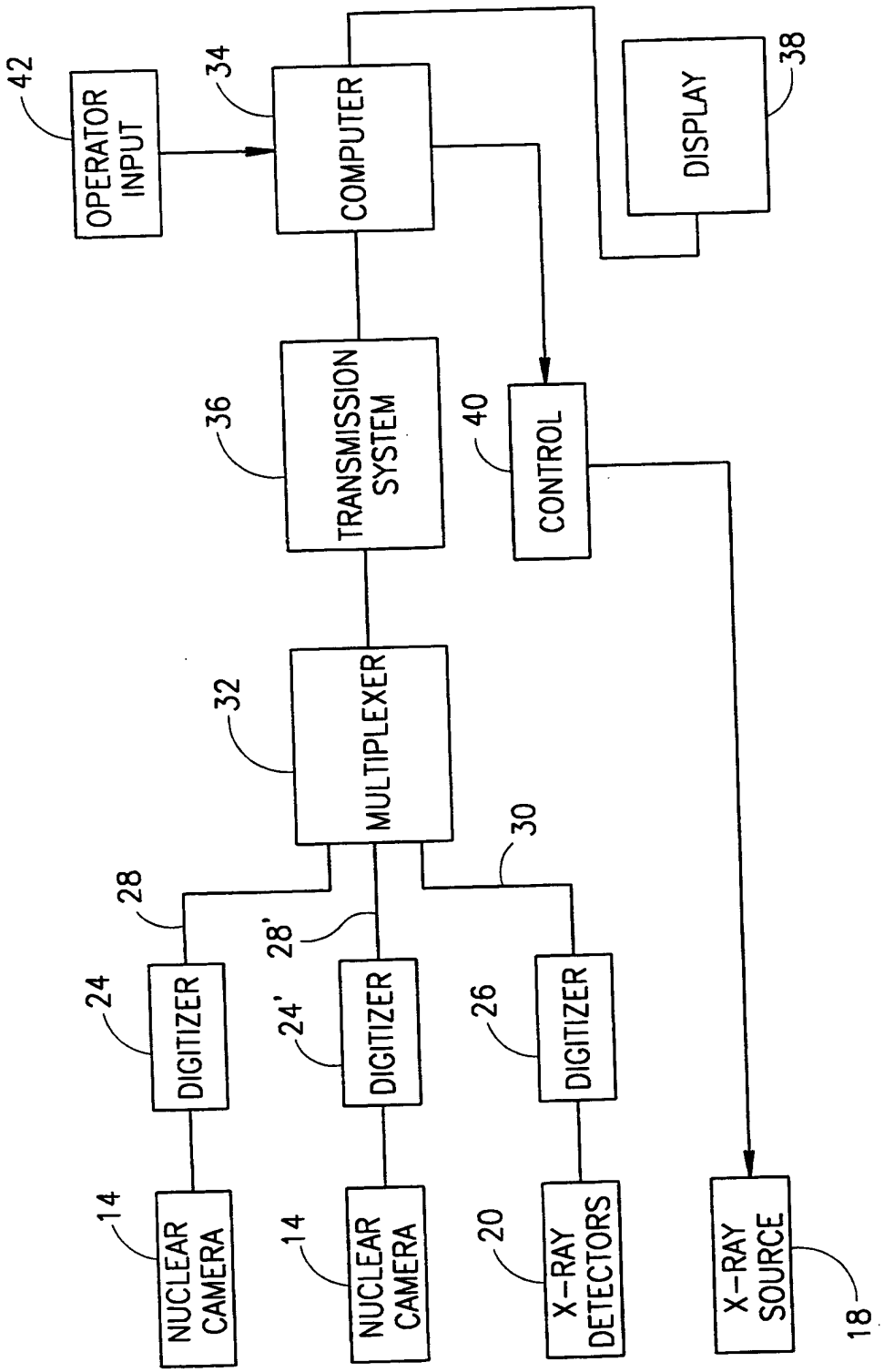

42
OPERATOR INPUT
34
COMPUTER
38
DISPLAY
36
TRANSMISSION SYSTEM
40
CONTROL
32
MULTIPLEXER
28
28'
30
24
DIGITIZER
24'
DIGITIZER
26
DIGITIZER
14
NUCLEAR CAMERA
14
NUCLEAR CAMERA
20
X-RAY DETECTORS
X-RAY SOURCE
18

FIG.1D

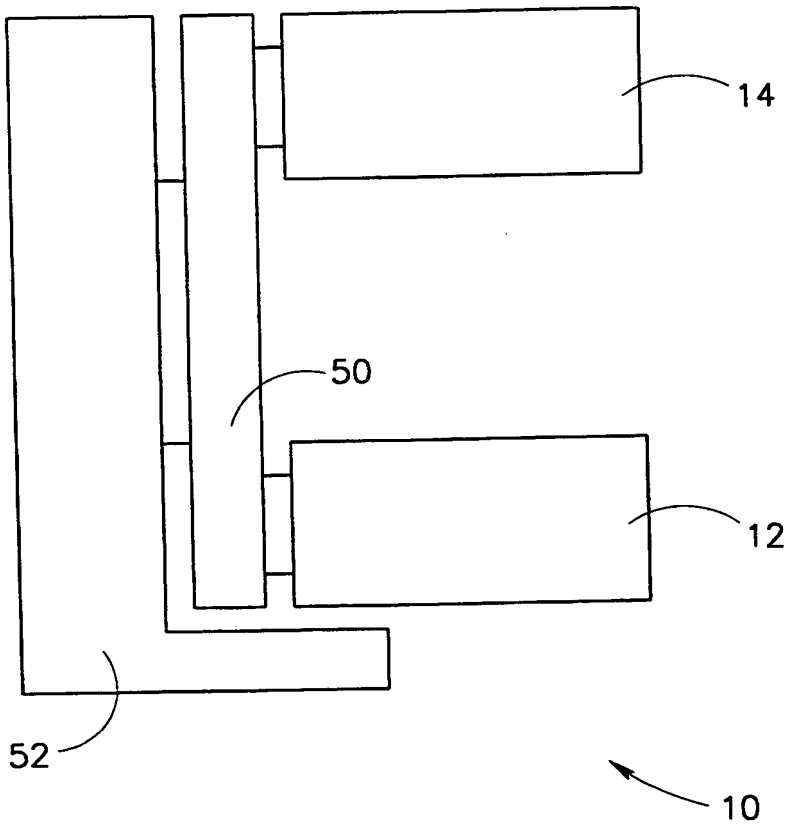


FIG.2

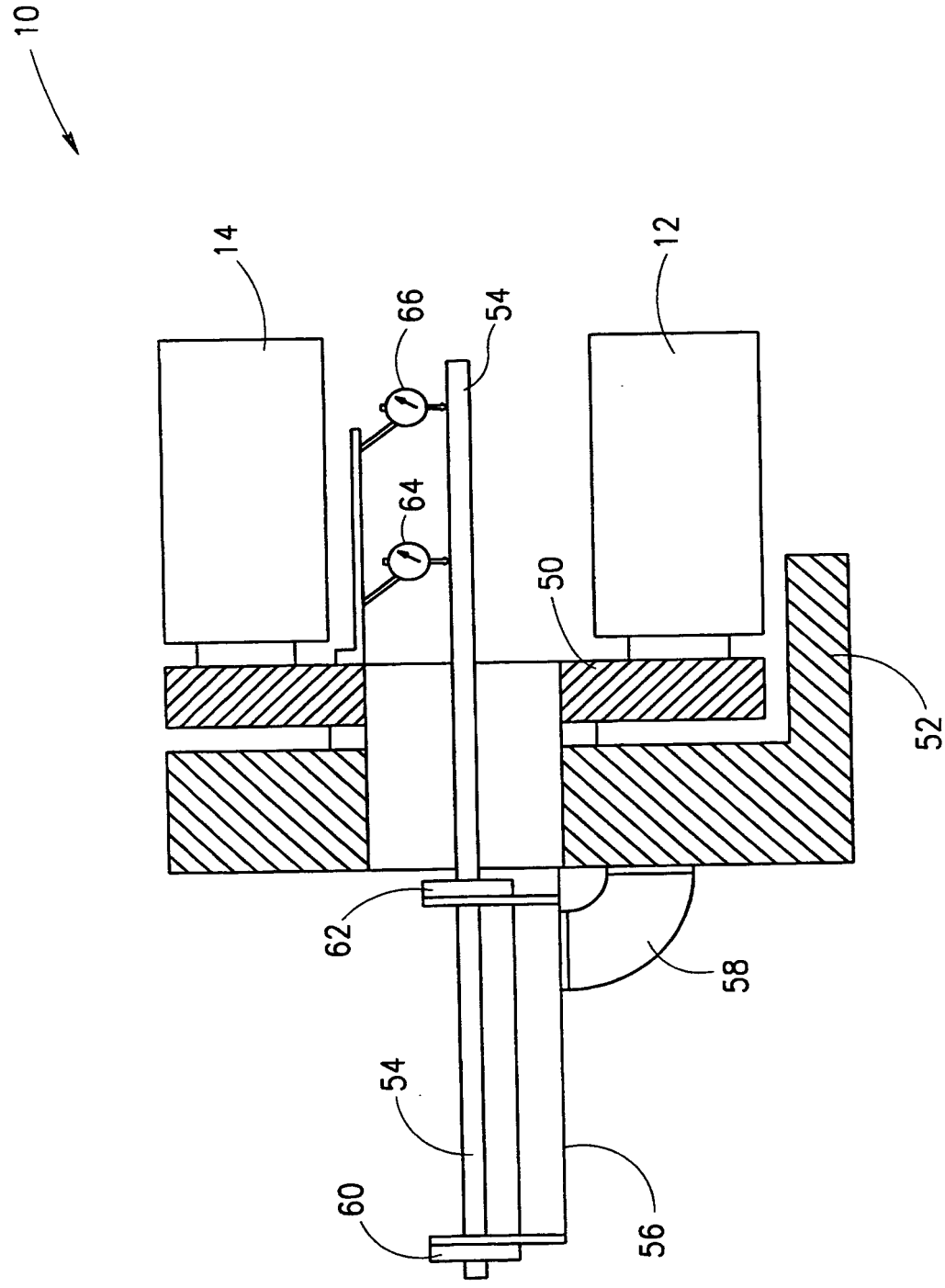


FIG.3

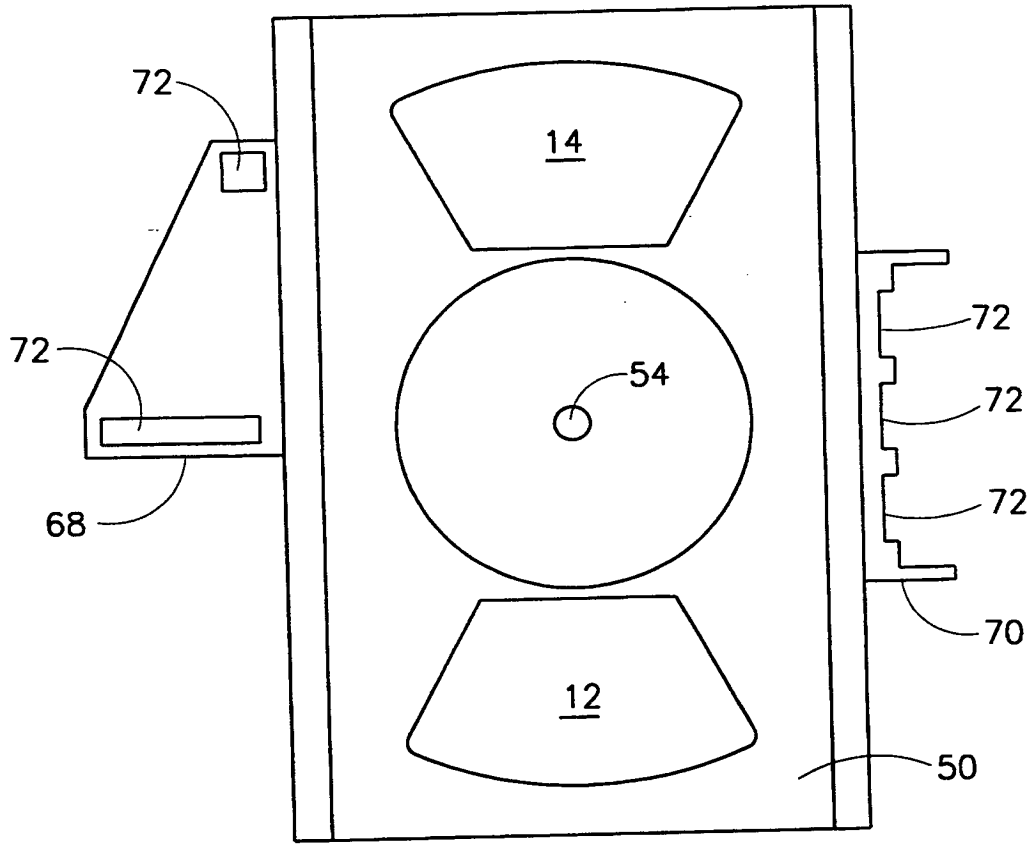


FIG.4

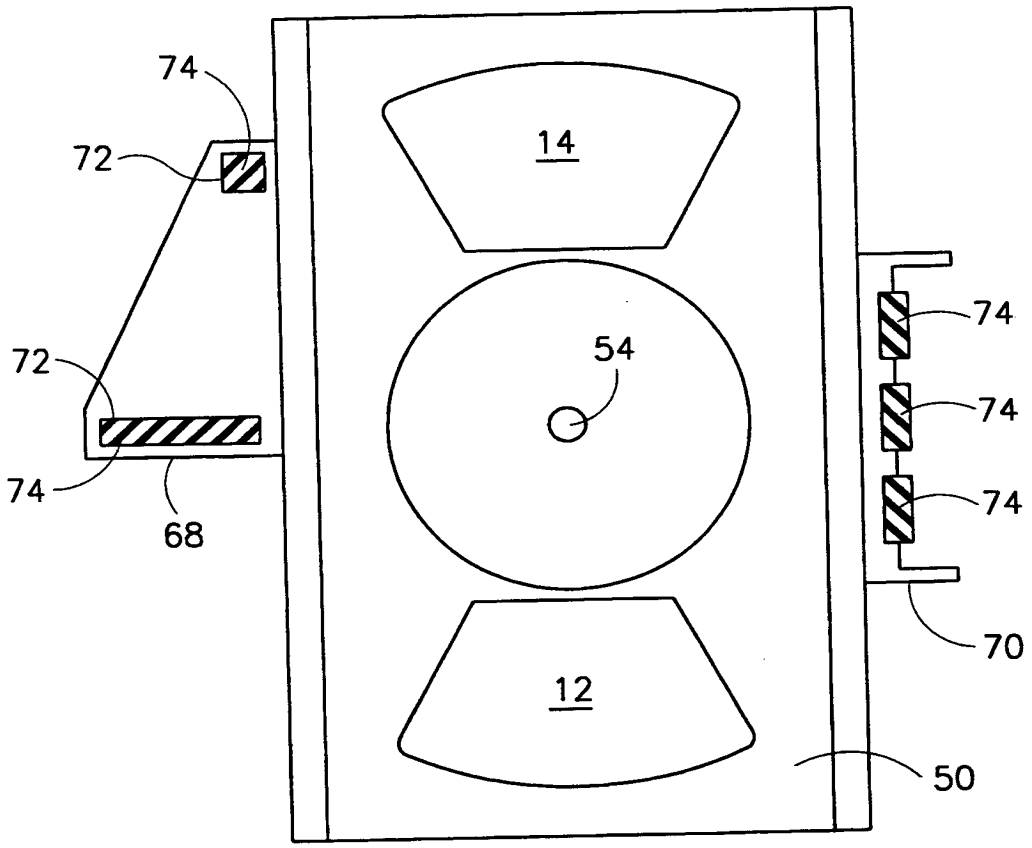


FIG.5

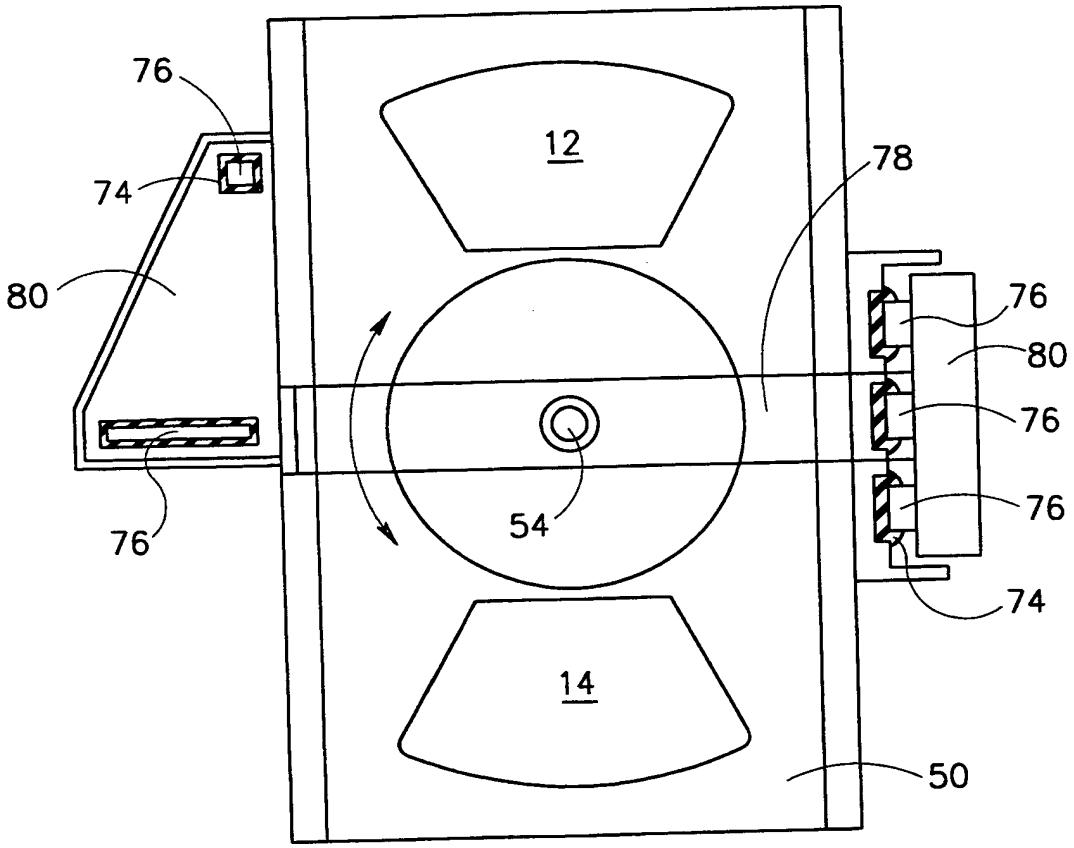


FIG.6

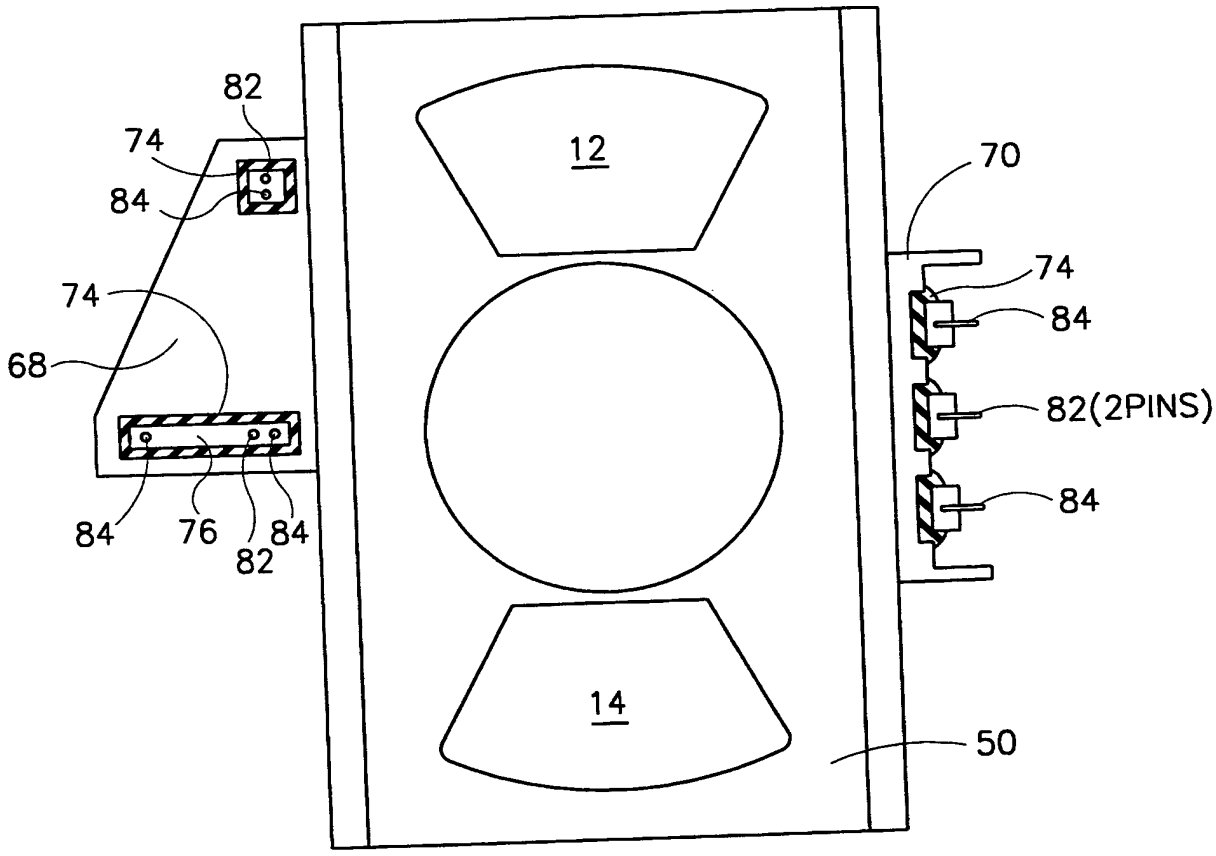


FIG.7

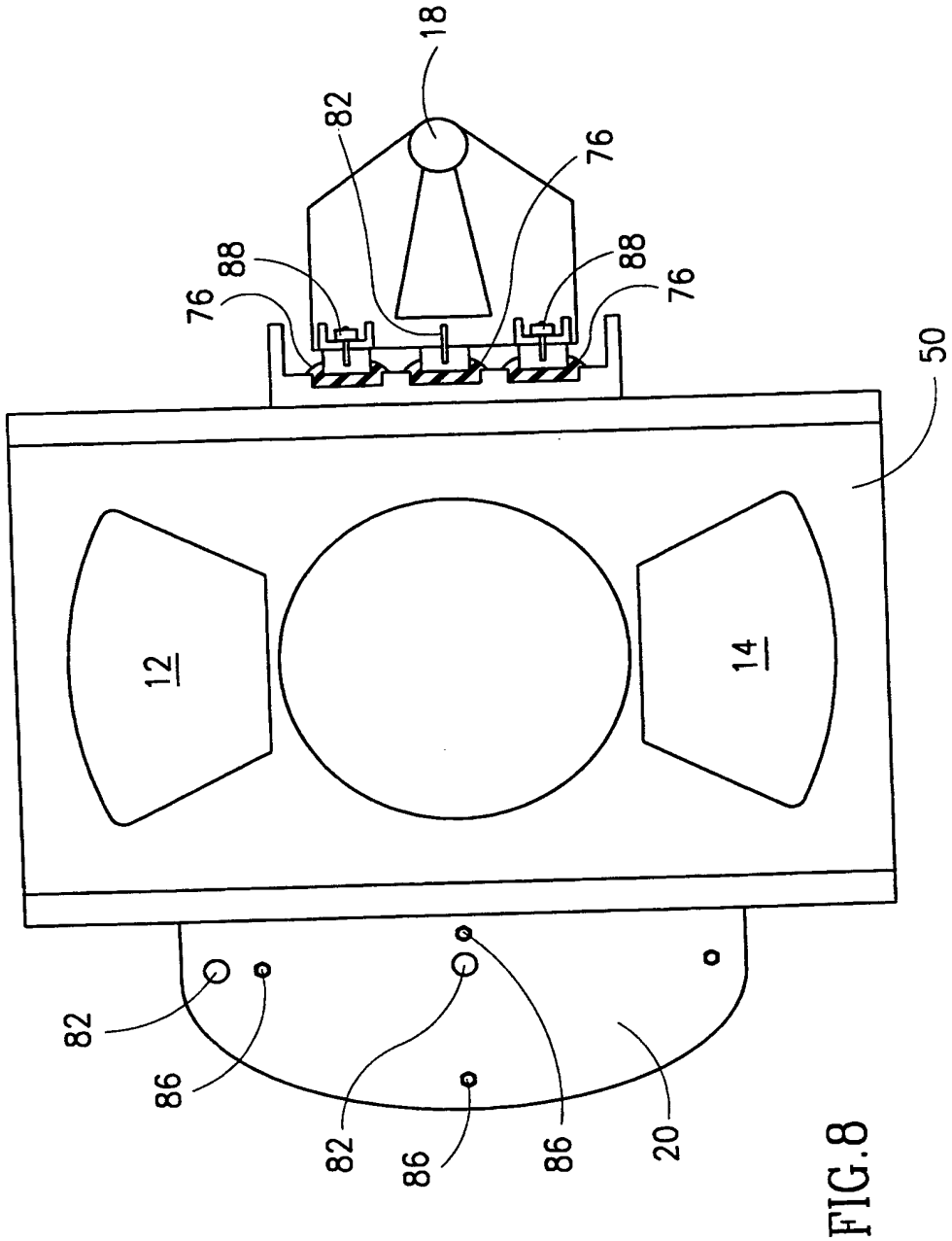


FIG.8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL99/00300

A. CLASSIFICATION OF SUBJECT MATTER

IPC(7) : G01T 1/00, 1/20
US CL : 250/363.04, 363.05, 363.08, 363.09

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 250/363.04, 363.05, 363.08, 363.09, 363.02, 378/4, 11, 15, 18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Please See Continuation Sheet

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5,565,684 A (GULLBERG et al.) 15 October 1996 (15.10.1996), abstract; col. 3, lines 55-58; col. 4, lines 30-39, 56-60; col. 6, lines 9-13; Figs 1-3.	1-3, 78
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Y		4-28, 31-41, 53-72, 75-77
Y	US 5,289,008 A (JASZCZAK et al.) 22 February 1994, (22.02.1994), abstract; col. 4, lines 38-50; Fig.	4-12
Y	US 5,598,003 A (JONES et al.) 28 January 1997 (28.01.1997) abstract; col. 2, line 67-col. 3, line 5; col. 6, lines 16-18, 62-65; Figs. 1-2.	10-15, 31
Y	US 4,585,008 A (JARKEWICZ) 29 April 1986 (29.04.1986), abstract, col. 7, lines 34-	16-28, 76-77
Y	US 5,391,877 A (MARKS) 21 February 1995 (21.02.1995), abstract; col. 2, lines 32-38, 62-69; Fig. 1.	16-28
Y	US 5,554,848 A (HERMONY et al.) 10 September 1996 (10.09.1996), abstract; col. 2, lines 36-47; col. 4, lines 55-67, Figs. 1-2.	16-28, 32-41, 75-77
Y	US 5,900,636 A (NELLEMANN et al.) 04.May 1999 (04.05.1999), abstract; Fig. 1.	53-72
X	US 4,014,109 A (SCHRAMM) 29 March 1977 (29.03.1977), abstract; Fig. 1.	79
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Y		80-97
Y	US 4,499,375 A (JASZCZAK) 12 February 1985 (12.02.1985), abstract; Fig. 1, 3.	80-97

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
11 April 2000 (11.04.2000)

Date of mailing of the international search report
26 APR 2000

Name and mailing address of the ISA/US
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Seungsook Robyn Ham

Telephone No. (703) 308-0956

Form PCT/ISA/210 (second sheet) (July 1998)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL99/00300

C (Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,803,914 A (RYALS et al.) 08 September 1998 (08.09.1998), see entire document.	1-41, 53-78
A	US 5,717,212 A (FULTON et al.) 10 February 1998 (10.02.1998), see entire document.	42-52
A	US 4,578,585 A (GOSIS et al.) 25 March 1986 (25.03.1986) see entire document.	42-52

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IL99/00300

Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claim Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claim Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claim Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:
Please See Continuation Sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest.

☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/IL99/00300

BOX II. OBSERVATIONS WHERE UNITY OF INVENTION IS LACKING This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claim(s) 1-41 and 53-78, drawn to a method and apparatus for producing attenuation corrected nuclear medicine images.

Group II, claim(s) 42-52, drawn to a method of mounting a CT imager on a gantry.

Group III, claim(s) 79-97, drawn to a registration phantom for registering transmission and emission images.

The inventions listed as Groups I, II, and III do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons:
Group I is directed to a group of inventions wherein the special technical features are directed to the production of nuclear medicine images comprising acquiring nuclear image data and x-ray data. The inventions of Group I lack special technical features directed to either mounting a CT imager on a gantry or a registration phantom for registering transmission and emission images.
Group II is directed to a group of inventions wherein the special technical features are directed to the mounting of a CT imager on a gantry. The inventions of Group II lack special technical features directed to either producing a nuclear medicine image or a registration phantom for registering transmission and emission images.
Group III is directed to a group of inventions wherein the special technical features are directed to a registration phantom for registering transmission and emission images. The inventions of Group III lack special technical features directed to either producing a nuclear medicine image or mounting a CT imager on a gantry.

Continuation of B. FIELDS SEARCHED Item 3: USPTO APS EAST search terms: emission, transmission, gamma, x-ray, attenuation correction, imaging, noise, resolution, hounsfield, phantom, registration, calibration, attach, mount, jig.